eti
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VOLUME 11

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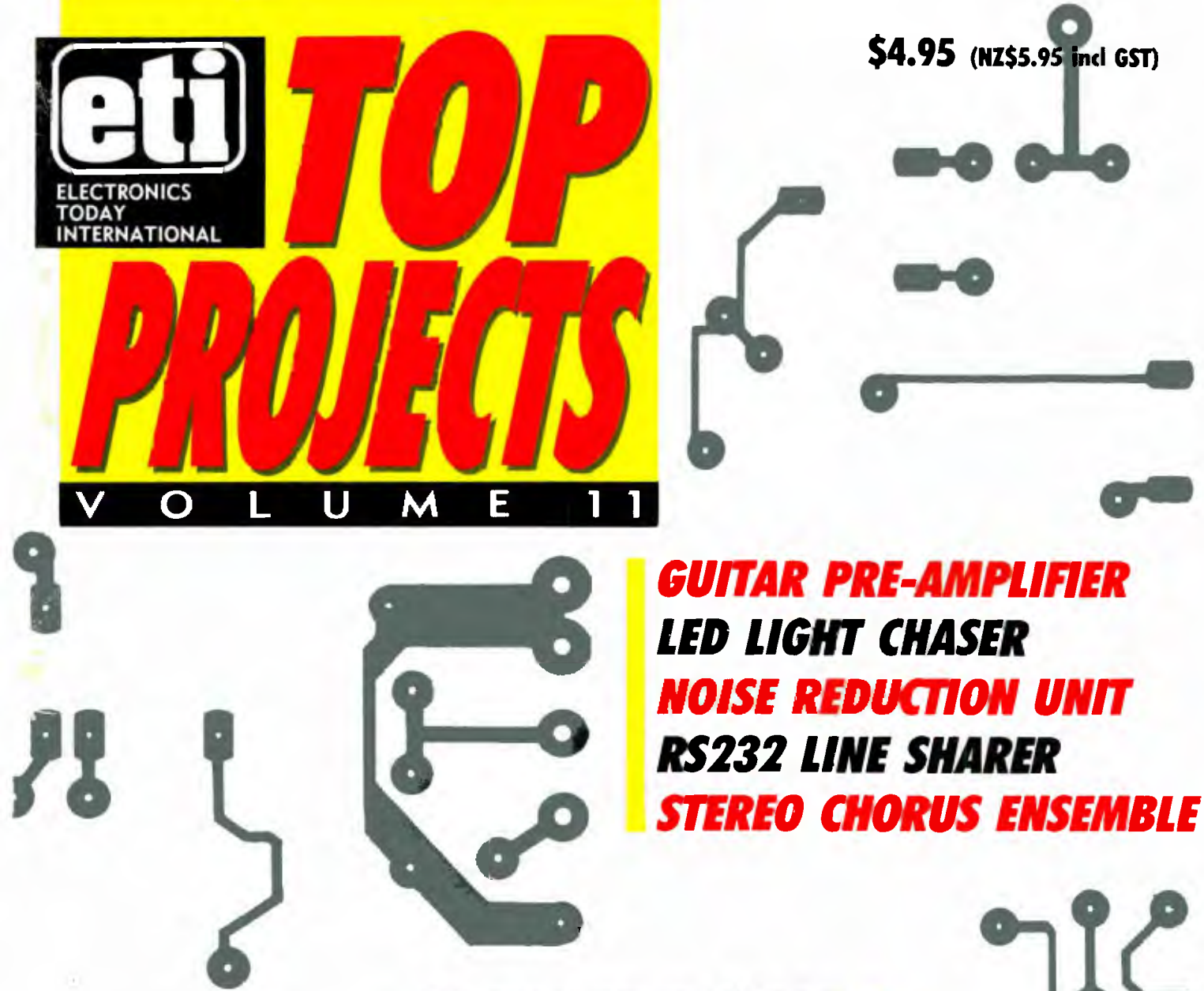
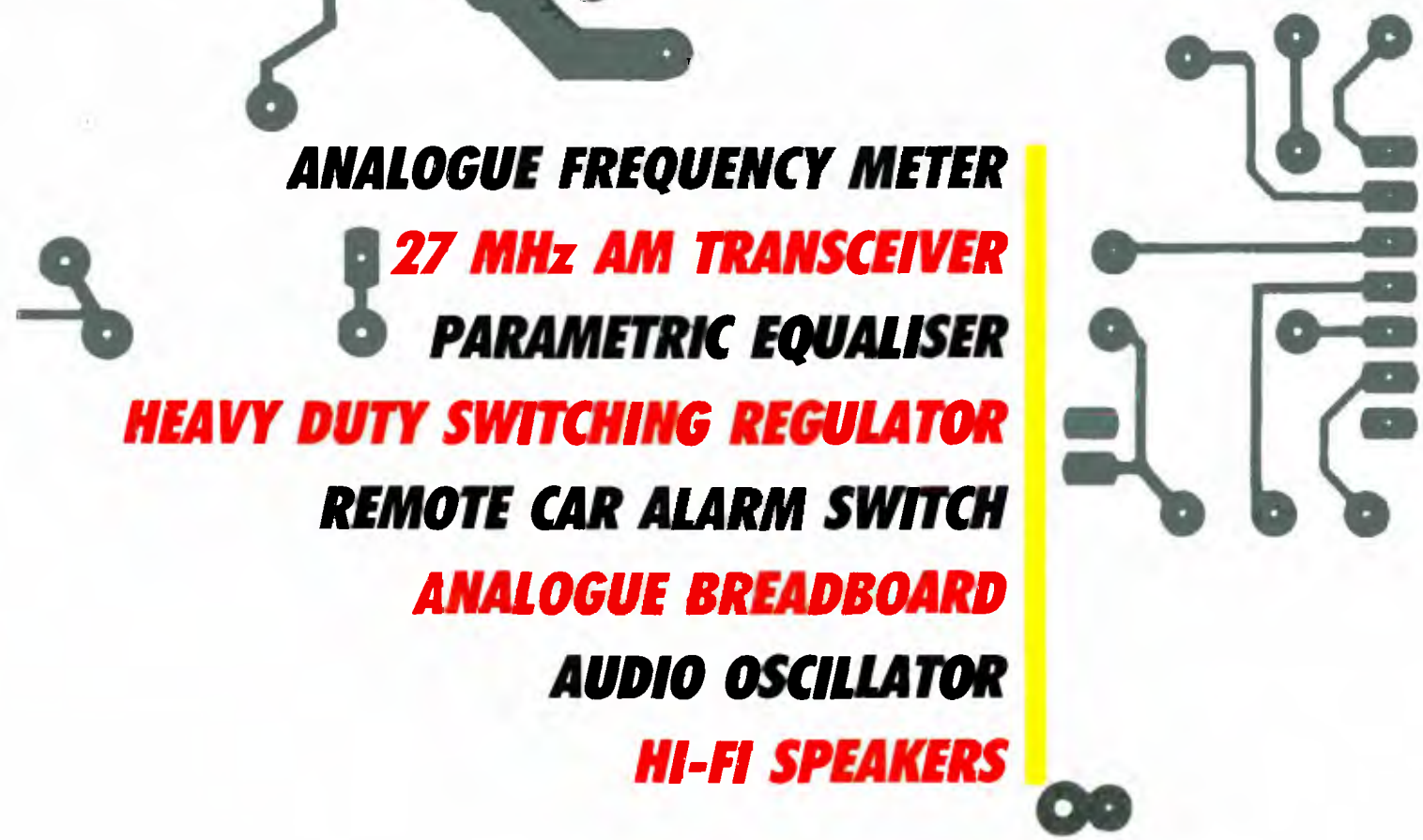


GUITAR PRE-AMPLIFIER
LED LIGHT CHASER
NOISE REDUCTION UNIT
RS232 LINE SHARER
STEREO CHORUS ENSEMBLE



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S4 ETI 482B Tone Control Board
S6 ETI 480 50 watt Amplifier
S7 ETI 480 100 watt Amplifier
S9 ETI 443 Expander Compressor
S10 ETI 444 Five watt stereo
S12 ETI 438 Audio Level Meter
S18 ETI 426 Rumble Filter
S35 ETI 470 60 watt audio amplifier module
S36 ETI 4000 Series 60 watt stereo amplifier
S37 ETI 451 Hum Filter for Hi-Fi systems
S38 E A Stereo Infrared Remote Switch
S39 ETI 455 Stereo Loudspeaker Protector
S40 E A Super-Bass Filter
S42 E A Stylus Timer
S43 ETI 3000 Series Amplifier 25 w ch
S44 ETI 477 Mosfet power amp module inc brackets
S45 ETI 457 Scratch Rumble Filter
S46 ETI 458 VU Level Meter
S47 ETI 479 Bridging Adaptor
S48 ETI 5000 Series Power Amplifier
S49 ETI 494 Loudspeaker Protector
S50 EA Infrared TV Sound Control
S51 HE 121 Scratch & Hiss Filter
S52 EA 100W Sub Woofer Module
S53 EA Stereo Simulator
S54 EA Headphone Amp
S55 AEM 6500 60W Utility Amp Module
S56 AEM 6500 100W Utility Amp Module
S57 ETI 1405 Stereo Enhancer
S58 ETI 442 Master Play Stereo
S59 EA Led Bar Graph Display (Stereo)
S60 E A AM Stereo Decoder
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S62 ETI 453 General Purpose Amp
S63 EA Bridge Adaptor
S64 AEM 6503 Active Cross-Over

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ST1 ETI 592 Light Show Controller (3 ch) (1000 w ch)
ST2 ETI 593 Colour Sequencer (for use with ETI 593)
ST4 E A Light Chaser 3 channel
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P19 ETI 478MC Moving Coil Pre amp (Series 5000)
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P24 EA Effects Unit
P25 ETI 1043 3 Channel Mixer
P26 ETI 588 Theatrical Lighting Controller

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G16 ETI 454 Fuzz Sustain
G17 HE 102 Guitar Phaser
G18 ETI 450A Bucket Brigade
G19 ETI 450B Mixer for above
G20 E A guitar Pre amplifier
G21 Sonics ME2 Sonics ME2 Wah Wah Pedal less pedal
G22 EA Effects Unit
G23 ETI 1410 Bass Guitar Amp (150W)

AUDIO TEST UNITS
AT1 ETI 441 Audio Noise Generator
AT2 ETI 128 Audio Millivolt Meter
AT7 ETI 137 Audio Oscillator
AT9 HE 105 Bench Amplifier
AT10 E A Audio Test Unit
AT11 E A Function Generator
AT12 ETI 464 Audio Test Unit

TIMERS
T1 ETI 650 STAC Timer
T2 ETI 564 Digital Wall Clock
T4 ETI 540 Universal Timer
T5 ETI 265 Power Down

T6 EA 4 Digit L C D Clock or Control Timer

COMMUNICATION EQUIPMENT
CE1 ETI 711 Remote Control Transmitter Switch
CE2 ETI 711R Remote Control Receiver
CE3 ETI 711D Remote Control Decoder
CE4 ETI 711B Single Control
CE5 Double Control
CE6 ETI 711P Power Supply
CE9 ETI 708 Active Antenna
CE11 ETI 780 Novice Transmitter
CE12 ETI 703 Antenna Matching Unit
CE33 ETI 718 Shortwave Radio
CE34 ETI 490 Audio Compressor
CE35 ETI 721 Aircraft Band Converter (less XTALS)
CE37 ETI 475 Wide Band A M Tuner
CE38 E A Masthead Pre-amplifier
CE39 ETI 731 R T T Y Modulator
CE40 ETI 729 UHF TV Masthead Preamp
CE41 ETI 735 UHF to VHF TV Converter
CE42 HE 104 AM Tuner
CE43 HE 106 Radio Microphone
CE44 E A R T T Y Demodulator
CE45 E A Voice Operator Relay
CE46 ETI 733 RTTY Converter for Microbee
CE47 ETI 1517 Video Distribution Amp
CE48 EA Video Enhancer
CE50 ETI 1518 Video Enhancer
CE51 EA VCR Sound Processor
CE 52 EA Motorcycle Intercom
CE 53 ETI 1405 Stereo Enhancer
CE 56 ETI 755 Computer Driven RTTY Transceiver

METAL DETECTORS
MD1 ETI 549 Induction Balance Metal Detector
MD2 ETI 561 Metal Locator
MD3 ETI 1500 Discriminating Metal Locator (unpainted case)
MD5 ETI 562 Geiger Counter with ZP 1310 Tube
MD6 ETI 566 Pipe and Cable Locator
MD7 E A Prospector Metal Locator (including headphones)

TEST EQUIPMENT
TE2 ETI 133 Phase Meter
TE9 ETI 124 Tone Burst Generator
TE16 ETI 120 Logic Probe
TE17 ETI 121 Logic Pulser
TE34 ETI 487 Real Time Audio Analyser
TE35 ETI 483 Sound Level Meter
TE36 ETI 489 Real Time Audio Analyser
TE37 ETI 717 Cross Hatch Generators
TE38 E A 3 Mhz Frequency Counter
TE39 EA High Voltage Insulation Tester
TE42 E A Transistor Tester incl BiPolar A F E T S
TE43 ETI 591 Up Down Pre-setable Counter
TE44 ETI 550 Digital dial (less case) includes ETI 591
TE46 ETI 148 Versatile Logic Probe
TE47 ETI 724 Microwave Oven Leak Detector
TF48 ETI 150 Simple Analog Frequency Meter
TE51 E A Digital Capacitance Meter
TE52 ETI 589 Digital Temp Meter
TE53 E A T V C R O Adaptor
TE54 E A XTAL Locked Pattern Generator
TE55 E A Decade Resistance Sub Box
TE56 E A Capacitance Sub Box
TE57 E A Decade Capacitance Sub Box
TE58 E A Tantalum Capacitance Sub Box
TE60 ETI 572 PH Meter
TE61 ETI 135 Panel Meter
TE63 HE 103 Transistor Tester
TE64 HE 111 Ohm meter
TE65 ETI 157 Crystal Marker
TE66 ETI 161 Digital Panel Meter
TE67 ETI 255 Analog Thermometer
TE68 EA Transistor Tester
TE69 ETI 175 20 MHz Dig Frequency Meter (Hand held)
TE70 ETI 166 Function Pulse Generator
TE 72 AEM 5505 Hash Harrier
TE 73 EA Event Counter
TE 74 ETI 183 OP-Amp Tester
TE75 ETI 577 Digital pH Meter

MODEL TRAIN UNITS (see also 'SOUND EFFECTS')
MT1 ETI 541 Model Train Contro
MT2 E A 197- Mode Train Control
MT3 EA Railmaster - Including Remote

SOUND EFFECTS
SE1 E A Sound Effects Generator
SE3 E A Cylon Voice
SE4 E A Steam Whistle
SE5 ETI 607 Sound Effects
SE6 E A 492 Audio Sound Bender
SE7 E A Electronic Sea Shell Sound Effects
SE8 ETI 469A Percussion Synthesiser
SE9 ETI 469B Sequencer for Synthesiser
SE10 EA Effects Unit
(set as for Steam Train and Prop Plane noise

VOLTAGE/CURRENT CONTROLS
V1 ETI 481 12 volt to ± 40v D C 100 watt Inverter
V2 ETI 525 Drill Speed Controller
V6 E A 1976 Speed Control
V10 E A Zero-voltage switching heat controller
V11 E A Inverter 12v D C input 230v 50 hz 300VA output
V12 ETI 1505 Flourescent Light Inverter
V13 EA Electric Fence
V14 ETI 1506 Xenon Push Bike Flasher
V15 ETI 1509 DC-DC Inverter
V16 ETI 1512 Electric Fence Tester
V17 EA Fluro Light Starter

V19 HE126 Nicad Charger
V20 ETI 578 Simple Nicad Charger
V21 EA Heat Controller
V22 ETI 563 Fast Ni-Cad Charger
V23 EA High Voltage Insultation Tester
V24 EA Electric Fence Controller
V25 ETI 1532 Temp Control For Soldering Irons

WARNING SYSTEMS
WS1 ETI 583 Gas Alarm
WS3 ETI 528 Home Burglar Alarm
WS4 ETI 702 Radar Intruder Alarm
WS7 ETI 313 Car Alarm
WS12 ETI 582 House Alarm
WS14 E A 1976 Car Alarm
WS15 E A 10 Ghz Radar Alarm
WS16 E A Light Beam Relay
WS17 ETI 247 Soil Moisture Indicator
WS18 ETI 250 Simple House Alarm
WS19 ETI 570 Infrared Trip Relay
WS20 ETI 585 T&R Ultrasonic Switch
WS21 ETI 330 Car Alarm
WS22 ETI 322 Over Rev Car Alarm (no case
WS24 ETI 1506 Xenon Bike Flasher
WS25 ETI 340 Car Alarm
WS26 EA Deluxe Car Alarm
WS27 EA Ultrasonic Movement Detector
WS28 ETI 278 Directional Door Minder
WS 29 EA Multisector Home Security System
WS30 EA Infra-Red Light Beam Relay
WS31 EA Deluxe Car Alarm
WS32 EA Doorway Minder
WS33 EA "Screecher" Car Alarm
WS34 ETI 1527 4 Sector Burglar Alarm

PHOTOGRAPHIC
PH1 ETI 586 Shutter Speed Timer
PH3 ETI 514B Sound Light Flash Trigger
PH4 ETI 532 Photo Timer
PH7 ETI 513 Tape Slide Synchronizer
PH12 EA Synca Slide
PH15 ETI 553 Tape Slide Synchronizer
PH16 E A Digital Photo Timer
PH17 ETI 594 Development Timer
PH19 E A Sound Triggered Photoflash
PH20 HE 109 Extra Flash Trigger
PH21 E A Photographic Timer
PH22 ETI 182 Lux Meter
PH23 ETI 1521 Digital Enl Exposure Meter
PH24 ETI 279 Exposure Meter

POWER SUPPLIES
PS1 ETI 132 Experimenters Power Supply
PS2 ETI 581 Dual Power Supply
PS3 ETI 712 CB Power Supply
PS4 ETI 131 Power Supply
PS9 E A 1976 Regulated Power Supply
PS11 E A C B Power Supply
PS12 ETI 142 Power Supply 0-30 V @ 1½ A (fully protected)
PS13 ETI 472 Power Supply
PS15 ETI 577 Dual 12V Supply
PS16 E A Power Saver
PS17 ETI 480 PS Power Supply for ETI 480 (100 watt Amp)
PS18 E A Bench Mate Utility Amp Pre Power Supply
PS20 ETI 1610 40 V 0.5 A
PS21 EA Dual Tracking Power Supply
PS22 ETI 162 1 3 30 Volt Fully Adjustable
PS23 ETI 251 OP AMP Power Supply

COMPUTER AND DIGITAL UNITS
C1 ETI 633 Video Synch Board
C2 ETI 632M Part 1 Memory Board VIC 20
C3 ETI 632P Part 1 Power Supply VIC
C4 ETI 632A Part 2 Control Logic VIC 20
C5 ETI 632B Part 2 Control Logic VIC 20
C6 ETI 632C Part 2 Character Generator VIC 20
C8 ETI 632 EARTH Board
C9 ETI 631 2 Keyboard Encoder
C10 ETI 631 A Sch Keyboard Encoder
C14 ETI 638 Eprom Programmer
C15 ETI 637 Cuts Cassette Interface
C16 ETI 651 Binary to Hex Number Converter
C17 ETI 730 Getting Going on Radio Tele Type
C24 ETI 760 Video RF Modulator

C25 E A Eprom Programmer
C26 ETI 668 Microbee Eprom Programmer
C27 ETI 733 RTTY Computer Decoder
C28 EA Video Amp for Computers
C29 ETI 649 Microbee Light Pen
C30 ETI 675 Microbee Serial — Parallel Interface
C31 ETI 688 Programmer for Fusable — Link Bipolar Proms
C32 ETI 676 RS232 for Microbee
* all V D U projects priced less connectors
C33 ETI 678 Rom Reader For Microbee
C34 ETI 659 VIC 20 Cassette Interface
C35 ETI 683 Mindmaster — Human Computer Link
C36 EA Eprom Copier/Programmer
C37 ETI 699 300 Band Direct-Connect Modem
C38 AEM 3500 Listening Post
C39 AEM 4600 Dual Speed Modem
C40 ETI 1601 RS 232 For Commodore
C41 AEM 4504 Speech Synthesizer
C42 ETI 181 Breakout Box

BIO FEEDBACK
BF1 ETI 546 G S R Monitor (less probes)
BF2 ETI 544 Heart Rate Monitor
BF3 ETI 576 Electromyogram

AUTOMOTIVE UNITS
A1 ETI 317 Rev Monitor
A2 ETI 081 Tachometer
A3 ETI 316 Transistor Assisted Ignition
A4 ETI 240 High Power Emergency Flasher
A6 ETI 312 Electronic Ignition System
A7 ETI 301 Van-Wiper
A14 E A Dwell Meter
A22 ETI 318 Digital Car Tachometer
A23 ETI 319A Varriwiper Mk 2 (no dynamic Braking)
A24 ETI 319B Varriwiper Mk 2 (for dynamic braking)
A25 ETI 555 Light Activated Tacho
A26 ETI 320 Battery Condition Indicator
A27 E A Transistor Assisted Ignition
A28 ETI 324 Twin Range Tacho less case
A29 ETI 328 Led Oil Temp Meter less V D O probe
A30 ETI 321 Auto Fuel Level Alarm
A31 ETI 332 Stethoscope
A32 ETI 325 Auto Probe Tests Vehicle Electricals
A33 ETI 333 Reversing Alarm
A34 E A Low fuel indicator
A35 ETI 326 Led Edpanded Voltmeter
A36 ETI 329 Ammeter (expanded scale)
A37 ETI 327 Turn and Hazard Indicator
A38 ETI 159 Expanded Scale Voltmeter
A39 EA Optoelectronic Ignition
A40 ETI 335 Wiper Controller
A41 EA Ignition Killer for Cars
A42 EA L C D Car Clock
A44 ETI 337 Automatic Car Aerial Controller
A45 ETI 280 Low Battery Volt Indicator
A46 ETI 322 Over Rev Alarm
A47 ETI 345 Demister Timer

ELECTRONIC GAMES
EG1 ETI 043 Heads and Tails
EG2 ETI 068 L E D Dice Circuit
EG3 E A Electronic Roulette Wheel
EG4 ETI 557 Reaction Timer
EG5 ETI 814 Dinky Die
EG6 E A Selectaloti
EG7 HE 107 Electronic Dice
EG8 E A Photon Torpedo
EG9 HE 123 Alien Invaders
EG10 EA Roulette Wheel
EG11 EA Chase N Chomp (Pac Man)

MISCELLANEOUS KITS
M1 ETI 604 Accentuated Beat Metronome
M4 ETI 547 Telephone Bell Extender
M7 ETI 044 Two Tone Doorbell
M10 ETI 539 Touch Switch
M25 E A Digital Metronome
M37 ETI 249 Combination lock (less lock)
M46 E A Power Saver for induction motors
M48 E A Lissajous Pattern Generator
M51 ETI 247 Soil Moisture Alarm
M55 E A Pools Lotto Selector
M56 ETI 256 Humidity Meter
M57 ETI 257 Universal Relay Driver Board
M58 E A Simple Metronome
M59 ETI 1501 Neg Ion Generator
M60 ETI 1516 Surp Start for Model Aeroplanes
M61 ETI 412 Peak Level Display
M62 ETI 1515 Motor Speed Controller
M63 ETI 1520 Wideband Amplifier
M64 EA Phone Minder

M65 EA Simple L C D Clock
M67 EA Ultrasonic Rule
M68 AEM 1500 Simple Metronome
M69 AEM 5501 Negative Ion Generator
M70 AEM 4501 8-Channel Relay Interface
M71 EA Pest Off
M72 ETI 606 Electronic Tuning Fork
M73 ETI 184 In Circuit Digital IC Tester

184 Incircuit digital IC Tester

287 Red Light Chaser

PLUS MANY, MANY MORE KITS WHICH WE CANNOT LIST HERE!!!
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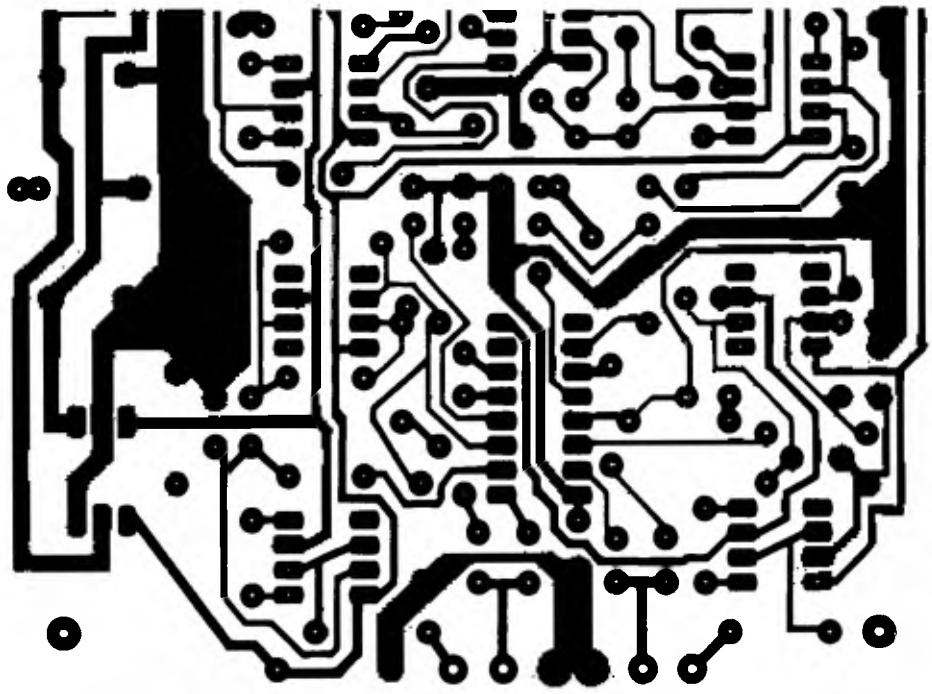
eti TOP PROJECTS

VOLUME 11



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Project 343

OPTICAL CAR ALARM SWITCH

Don't be fooled! This is not a torch at all but an optical car alarm switch. It consists of a transmitter (explained in Part 1) and receiver (Part 2) to deactivate car alarms and thus avoid delay mechanisms that can be exploited by the unwanted intruder. The project requires a little mechanical dexterity, but don't be too alarmed — we managed it!

S. K. Hui **Part 1**

THIEVES AND BURGLARS are getting really professional nowadays. A quick check of police or NRMA statistics will show that many of the stolen cars are equipped with alarm systems. The ordinary car alarm no longer gives you much protection at all! Scrapping the old one and installing a new sophisticated system is the best solution, but it's really expensive — you might be looking at $300 or more.

Many classy cars, like the Renault Feugo or new BMW have built-in alarm systems. These have one common feature — remote turn off of the alarm, unlike most of the "do it yourself" alarm systems, which work on an entry delay. Such delays are usually adjustable up to tens of seconds. Unfortunately, a skilled burglar can disable your alarm within a few seconds.

There is one inexpensive way to update your alarm system. The ETI-343 Optical Car Alarm Switch. It is intended to be used with the most stupid car alarm system and turns it into something like the BMW's.

The idea is fairly simple. You turn the entry delay in your existing alarm to minimum time. Any unauthorized person trying to open the door or the boot will trigger the siren instantly. A little pocket size transmitter is used to turn off the alarm through the window before you get in. You can program your own transmitter code, which has n x 32 x 1024 different combinations. It is possible to have n number of different rates to clock out the code. Theoretically, n is an infinite number, but in this article, n is chosen to be three, ie, three different sets of resistors and capacitors are given in Table 1 for different rates of transmission. A different set of components will give you a different bit rate of transmission. Two transmitters with the same code but different bit rates will not interfere with each other. It is possible for you to invent a new transmission rate (bit rate) which is not listed. The only trouble is that you have to go through the calculation of the component values, and you need enormous patience to tune the receiver oscillator to the correct value. This will be discussed in the next issue.

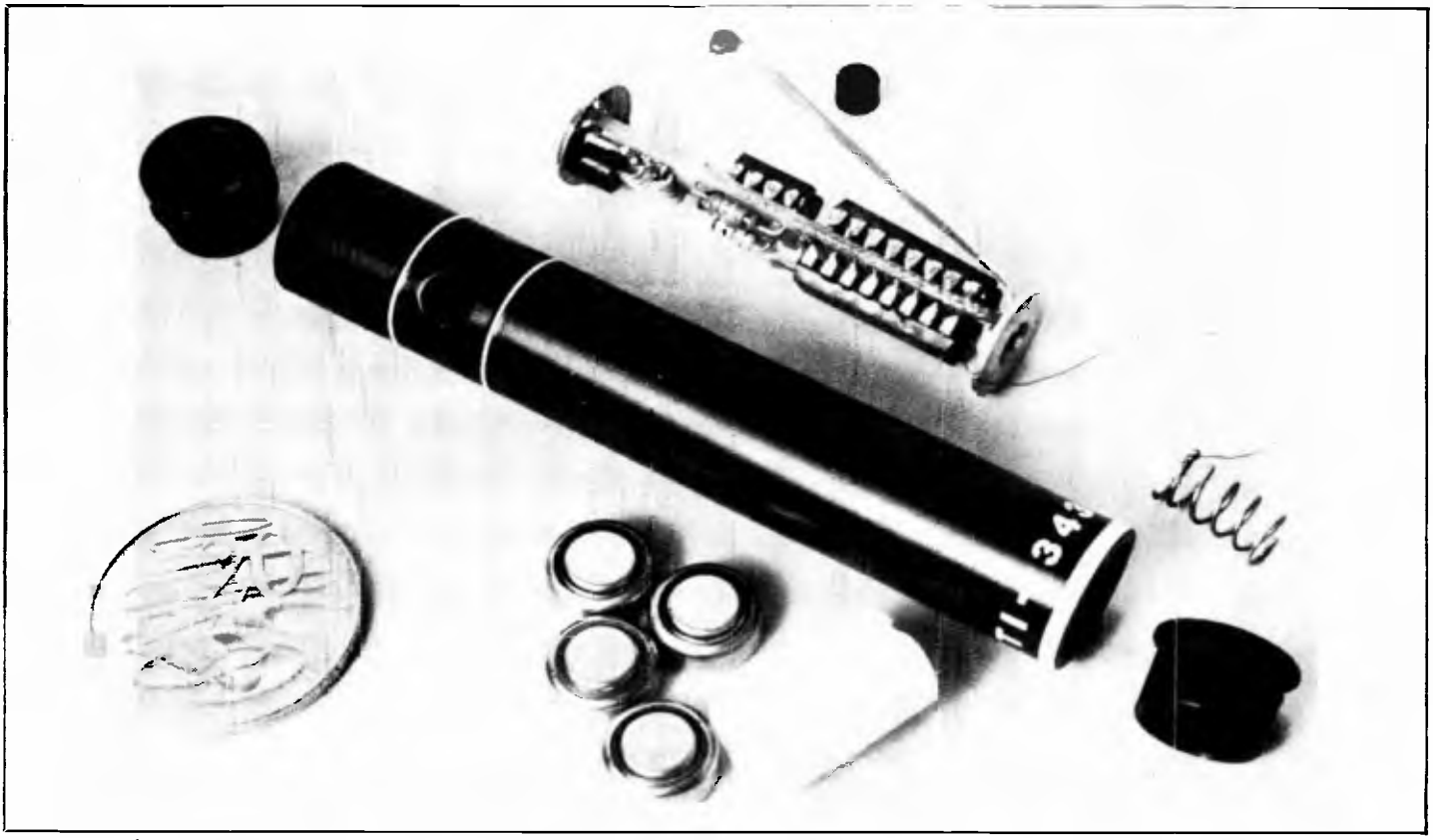
This project can be used in other applications. Turning off your car alarm is one typical application. I am sure many of you can figure out other innovative ways of using it.

Principle of transmitter circuit

The whole system works on the principle of asynchronous communication. It is a bit like the 6850 ACIA (asynchronous communication interfacing adaptor). Those who are not familiar with this device will find the following useful.

Suppose an 8-bit code, eg, 10011110 is transmitted. If the code is clocked out by the rising edge of the transmitter clock, the waveform of the data will look like that in Figure 1a. This same waveform is sampled at the receiver end with a sampler circuit. According to the Nyquist sampling theorem, the rate of the sampling has to be at least twice as fast as the maximum data rate in the transmitter. The sampling circuit is controlled by an oscillator. Usually there is a drift in the oscillator due to environmental factors such as temperature. The drift in the sampling rate can be minimized by having the oscillator oscillating many times faster than the actual sampling rate. The frequency of the oscillator is then divided down to give the correct sampling rate. Since nothing is perfect in this world, drift in the sampling rate can never be gotten rid of completely.

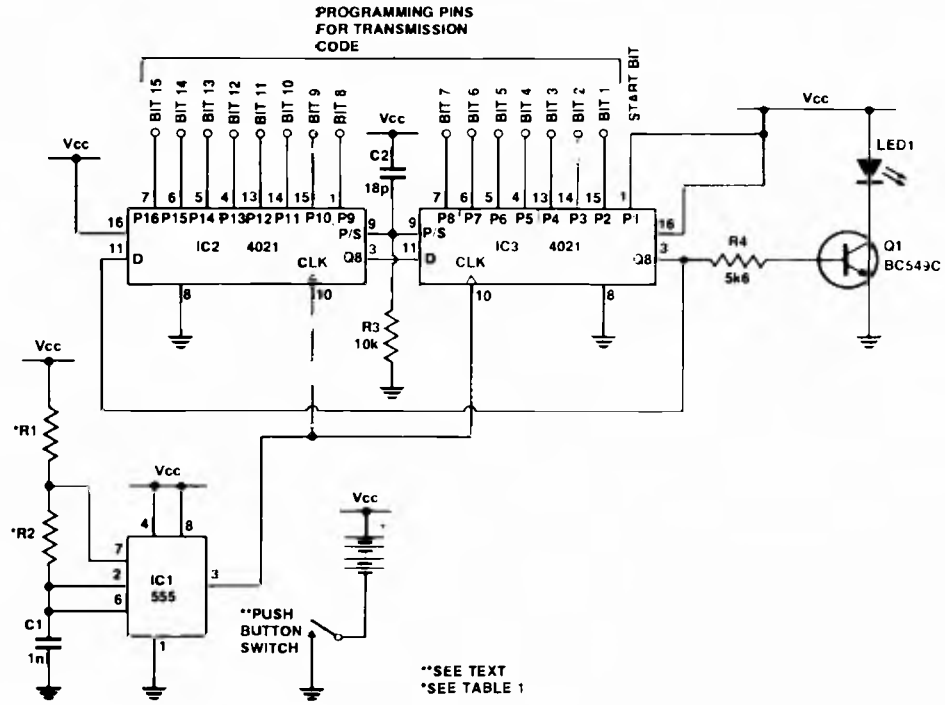
The ideal sampling point is in the middle of the mark (logic 1) or in the middle of a space (logic 0). This is shown in Figure 1b. The first bit transmitted is called the start bit and is used to synchronize the receiver oscillator. This allows the start bit to be sampled right in the middle. Since the transmitter clock is not transmitted to the receiver, the subsequent samples are controlled by the receiver oscillator which is not synchronized to the transmitter clock. The receiver oscillator is almost certainly drifting in the oscillator relative to the received signal. The effect is, as shown in Figure 1b, that the sampling points are drifting away from the middle of the bits. Eventually, wrong samples will be taken. In practice there is a limit to the maximum length of the word one can transmit without re-synchronizing the oscillator with the next start bit. In standard formats, the word normally contains a start bit, seven or eight bits of data, a parity bit and one or two stop bits. In our particular case, only one start bit is



All these parts fit into this compact transmitter making it an extremely 'handy' device

HOW IT WORKS — ETI-343

The transmitter circuit is very simple. Pin 1 of IC3 is always connected to logic high. This is the start bit. The batteries are connected to the circuit when the button is pressed. Pin 9 of IC2 and IC3 will go high immediately because of the capacitor C2. The logic pattern at pin 1 of IC2 and pin 15, 14, 13, 4, 5, 6, 7 of IC2 and IC3 is loaded parallel into the shift registers (IC2, IC3). The voltage of pin 9 of IC2 and IC3 gradually dies away according to a time constant formed by C2 and R3. As soon as this voltage goes low, control of the 4021s shifts to the serial mode. The clock input, pin 10, is driven by an 555 set up as an oscillator. The bit in pin 1 of IC3 gets shifted out first, the bit in pin 15 of IC3 is shifted out second, and so on. Any bit shifted out at pin 3 of IC3 also 'circulates' back to pin 11 of IC2. Repeated transmission of the same code is possible under this scheme. Components R1, R2 and C1 determine the clocking rate of the data from the following equations:



$$F_{CK} = \frac{1.443}{(R1 + R2 + R2) \times C1 \text{ Hz}}$$

$$\text{Duty cycle of clock} = \frac{R2 + R1}{(R1 + R2 + R2)}$$

The start bit normally turns LED1 on longer than other bits. This is because during the parallel loading of the registers, the start bit is active at pin 3 of IC3 already. The start bit stays active for one period of the clock plus the loading time. Therefore, the loading time constant of the register is made small compared to the clock period. That is, C2 and R3 are small.

As I said before, three different transmission rates are given in Table 1 with their component values already calculated. If any reader wants to use a transmission rate not listed in the table, the above formulas can be used. Whatever rate you choose, make sure it is not faster than the fastest given in the table, otherwise, the loading time of the registers becomes comparable with the clocking period. This might upset the sampling mechanism in the receiver.

used and the rest of the 15 bits are used as data (code).

The design of this project is based on the same principle. Two 8-bit shift registers are cascaded into a 16-bit shift register. Pressing the ON button will load a pre-programmed bit pattern to the shift register. The oscillator will clock out the data in the shift register one bit at a time. If the particular bit shifted out is a one, it turns on the LED, otherwise it turns the LED off. In order to increase the signal-to-noise ratio at the receiving end, it is recommended to use a high efficiency LED with at least 500 mcd output power. The registers are connected in a circulating fashion: any bit shifted out of the shift register will also be shifted back to the last bit of the 16-bit train. So long as your finger is pressing the button, the code will be transmitted repeatedly. As opposed to the one shot transmission, I've found that this technique allows greater drift in the receiver clock before errors start to occur.

Transmitter construction

The transmitter circuit is very simple, but fiddly work when you come to construct it. This is unavoidable as there are so many things that have to be squeezed into a tiny space of about 12.2 cubic cm. The order in which the components are placed on the board is important. Pads on the pc board with a small middle hole have to be drilled with a 0.8 mm drill bit. Solid pads should be left alone. The first job you have to do is program your own transmitter code by cutting the tracks on the pc board. The pads where pins 15, 14, 13, 4, 5, 6 and 7 of IC2 and IC3, and pin 1 of IC2 are to be soldered to have ground and Vcc connected to them through thin tracks. Initially then, the positive and negative supply rails are short circuited.

Now, if you want to program pin 7 of IC3 to be a '1', you have to cut the track joining the ground to the pad. If a '0' is desired, cut the track connecting Vcc to that pad instead. Never cut both tracks, or the pad will have floating state input. After cutting the fifteen tracks, it's good practice to measure the resistance between ground and Vcc. If they have zero or just a few ohms resistance, you'd better go back and check your cutting. Also, check that all the relevant pins are shorted to one rail or the other.

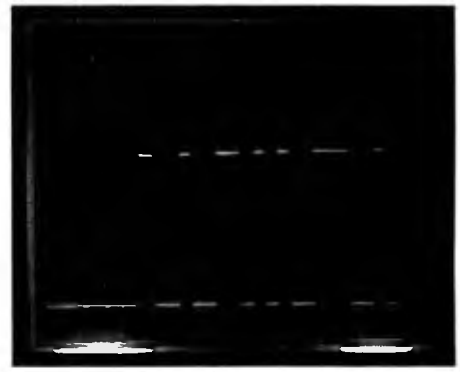
Because of lack of space available on the pc board, six flying wires are used. Thin 32 BNS insulated copper wire is preferred over normal hook up wire. The wires' labelling is as follows (please see the overlay diagram):

Wire A: connects from the Vcc track on the pcb to the spring;
Wire B: connects pin 3 of IC1 to pin 10 of IC2;
Wire C: connects pin 3 of IC2 to pin 11 of IC3;
Wire D: connects pin 3 of IC3 to pin 11 of IC2;
Wire E: connects pin 16 of IC2 to the anode of LED1;
Wire F: connects pin 3 of IC3 to resistor R4 as shown in the overlay.

It is important to solder wires B, C, D before any components. Then solder the resistors and the capacitors onto the pc board. Next, solder one of the Vcc brass washers on to one end of the pc board where the LED is going to be soldered on. Make sure the washer forms a right angle with the pc board. With some fiddling, you can insert the LED pins through the hole on the washer and solder them onto the board. It will be necessary to cut the pins to the right length and bend them to fit. You should make sure that the pins, after they are soldered to the board, do not touch the washer and are strong enough to hold the LED in position. Otherwise, the LED might short circuit the board and anything could happen. The remaining washer can be soldered to the other side of the board. Once again, the washer has to be at right angles to the pc board.

Cut a section of insulated copper wire about 9 cm long and solder one end of it onto the pc board as shown in the overlay and the other end to the spring. This is the wire labelled A.

The next component to be soldered is the transistor. Leave enough length on its pins so that you can bend the transistor over after it's been soldered. If you leave it vertical, it will be too high to go into the aluminium tube. Now you can solder all the ICs onto the board, then the wires E and F must be soldered directly onto the assigned pins of the ICs (see the overlay). The other



The 'captured' code. This photo shows the code "1" 0010011010100 — 1001 . . . which repeats itself. Note that the "1" (the first start bit) is longer than the other "1s" because of the parallel loading time. Horizontal scale: 5 ms/div; vertical scale: 1 V/div.

R1	R2	C1	555 TIMER OUTPUT	PERIOD OF CLOCK $T = T_1 + T_2$	TRANSMISSION RATE $F_{CK} = 1/T$
33k	270k	1nF	T_1 = 0.21 ms T_2 = 0.187 ms	T = 0.397 ms	2519 BITS/S
82k	470k	1nF	T_1 = 0.3825 ms T_2 = 0.3257 ms	T = 0.7082 ms	1412 BITS/S
680k	680k	1nF	T_1 = 0.9425 ms T_2 = 0.47124 ms	T = 1.414 ms	707.3 BITS/S

$T_1 = 0.693\ (R1 + R2)\ C1$
$T_2 = 0.693\ (R2)\ C1$

Table 1. Listed component values determine the clocking rate of the code (transmission rate). Same codes with different transmission rates do not interfere with each other.

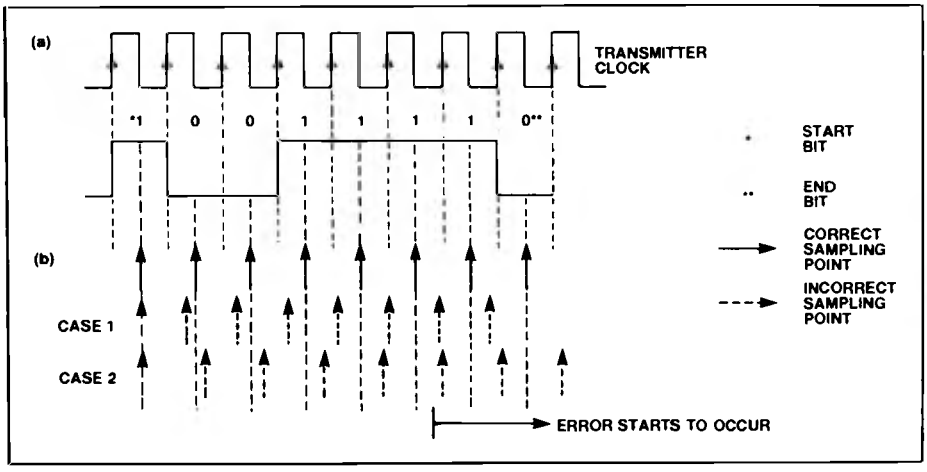
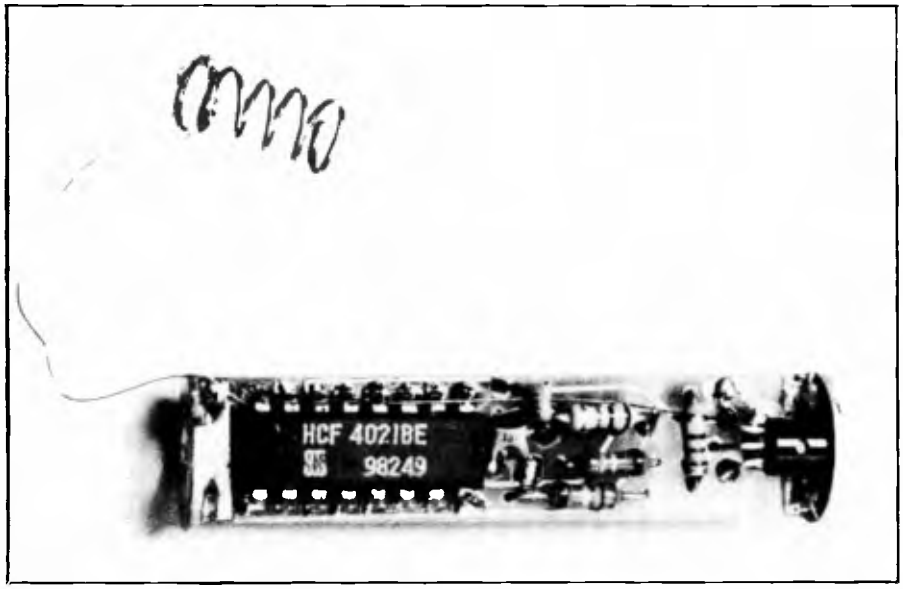
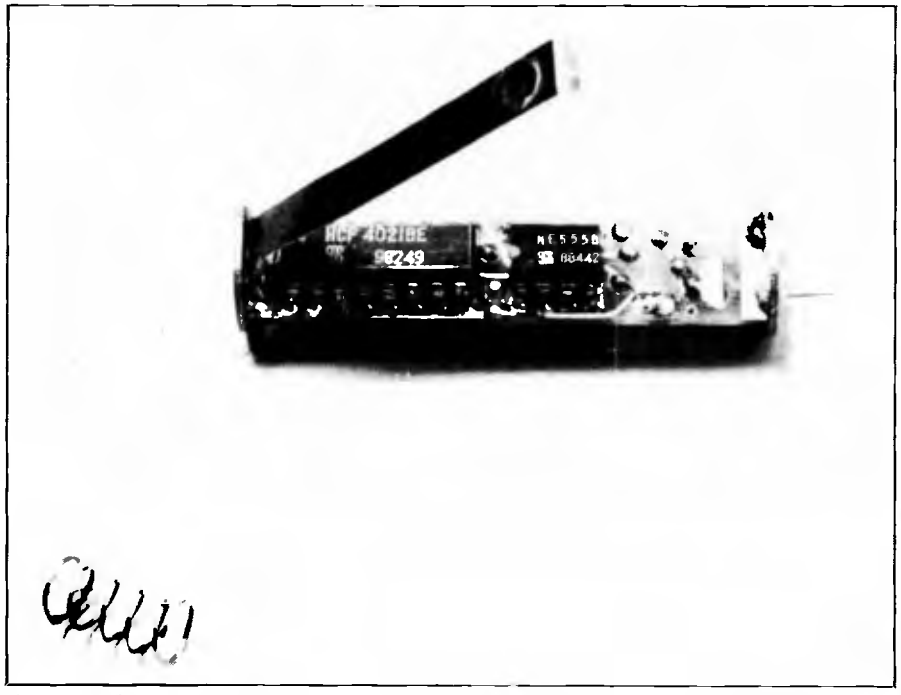


Figure 1. A drifting receiver clock affects the sampling instant. The sampling points drift away which results in error when the same data bit is sampled twice or missed.



The pc board showing side A components.



The pc board showing side B components.

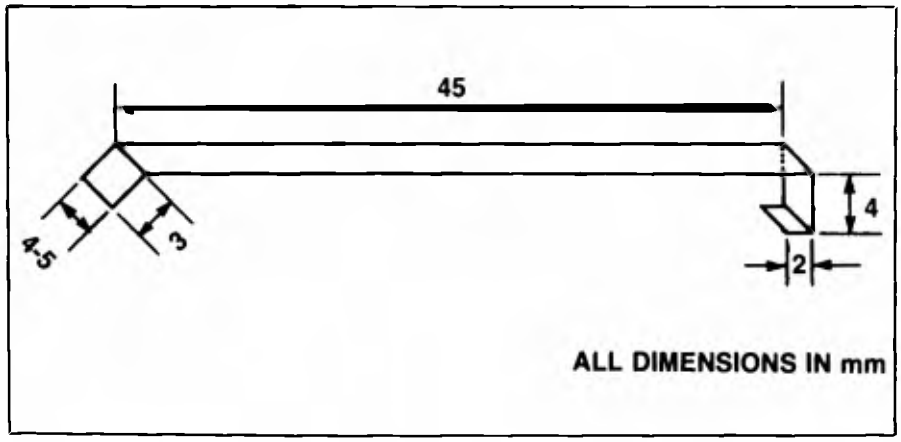


Figure 2. Bending diagram for the copper strip to make a pushbutton switch.

ends are soldered on to the pc board normally. Be careful during this operation. Quite often when you think the copper wires are soldered on, they are not. The insulating material melts and keeps the wire in position even though the copper is still unconnected to the track.

A meter should be used to check the resistance between the two points that are joined by the wire. Because the surface mounting technique is used here for the ICs, you have to cut their pins and solder them directly on the pads. Another point to look for: wire A has to reach the batteries from the pc board. Inevitably, it has to go past the rim of the brass washer, which is a tight fit in the tube. To avoid the wire being trapped in between the tube and the washer, a small slot can be filed in the rim of the washer using a needle file.

The last thing you have to do is make a pushbutton switch for the transmitter. Cut a strip of copper or brass (28G or 30G) about 60 x 4 mm. Bend it and solder it onto the board as shown in Figure 2. The other end of the copper strip is bent so that it is about to touch the tinned contact on the board. The copper strip is now acting like a cantilever and only a slight push near the end should cause the contact to make. Now put the transmitter circuit, including the batteries and the plastic ends into the aluminium tube. The tube is 94 mm in length and the inner diameter is 13 mm.

Next drill a hole for the pushbutton itself: this will be 5 mm in diameter, its centre sited 21 mm from the end of the tube. The plastic knob is inserted through the hole; it will land on the end of the copper cantilever (see Figure 3). When operated this efectively connects the batteries to the circuit and activates the transmission. To improve the quality of your 'home made' pushbutton switch, tin the tip of the copper strip with solder.

Now you are ready for a test. Push the button and see whether the LED lights up. If everything is OK, take out the knob, scratch the copper strip at the point where the knob is going to be glued on. Put a drop of glue onto the copper strip through the hole on the aluminium tube, press the plastic knob back on and allow time for the glue to dry. To make the transmitter more reliable against shock, a few drops of araldite can be put in the gap between the washers and the inner wall of the tube to fix the pc board.

Testing and setting up

Normal practice is to construct a circuit, first, set it up and then, if it is not working, troubleshoot it. Because of its compactness and the surface mounting technique used in this circuit, it will be very difficult to correct any mistake once the circuit is built. To make sure everything works the first time, the following points should be observed si-

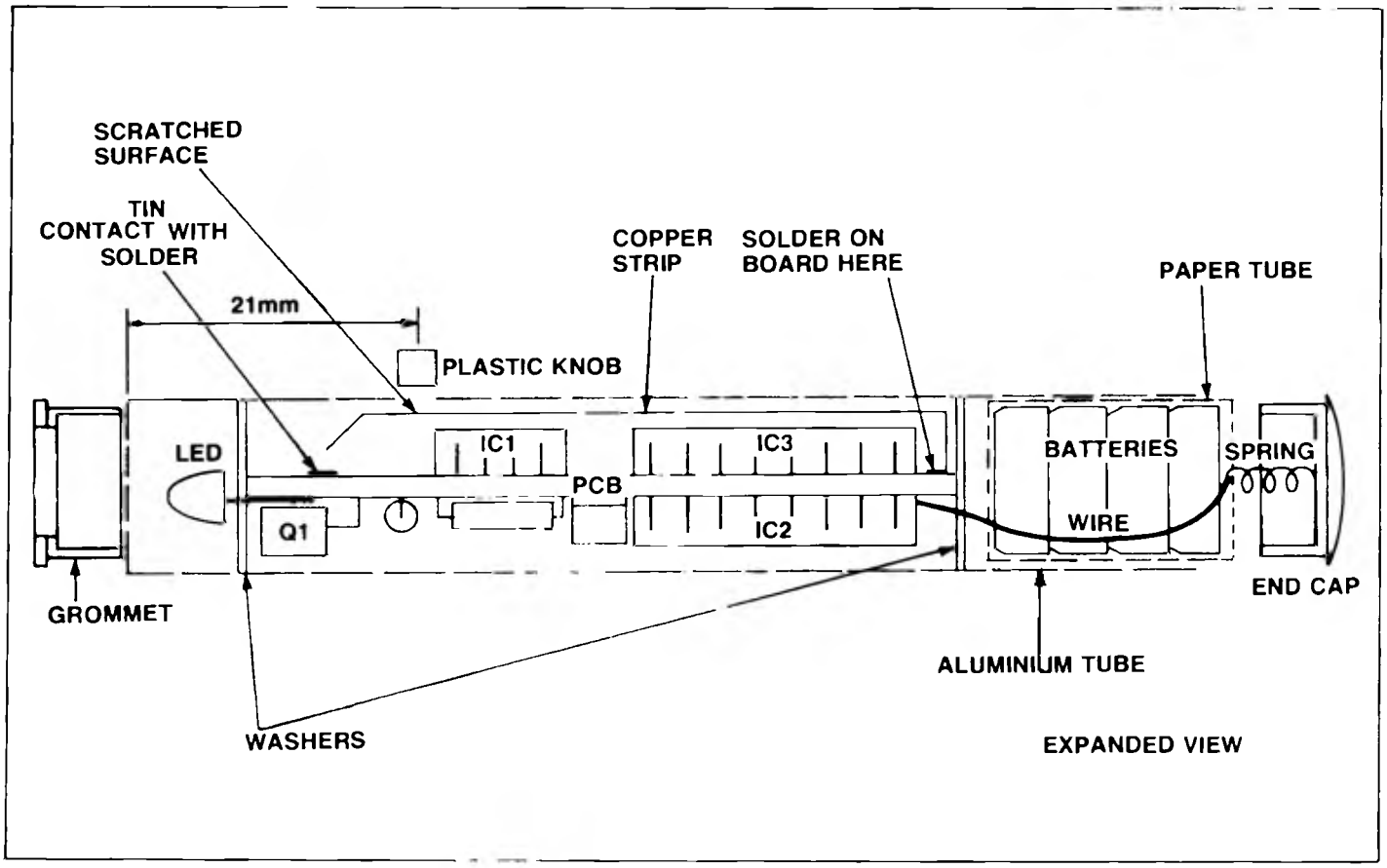
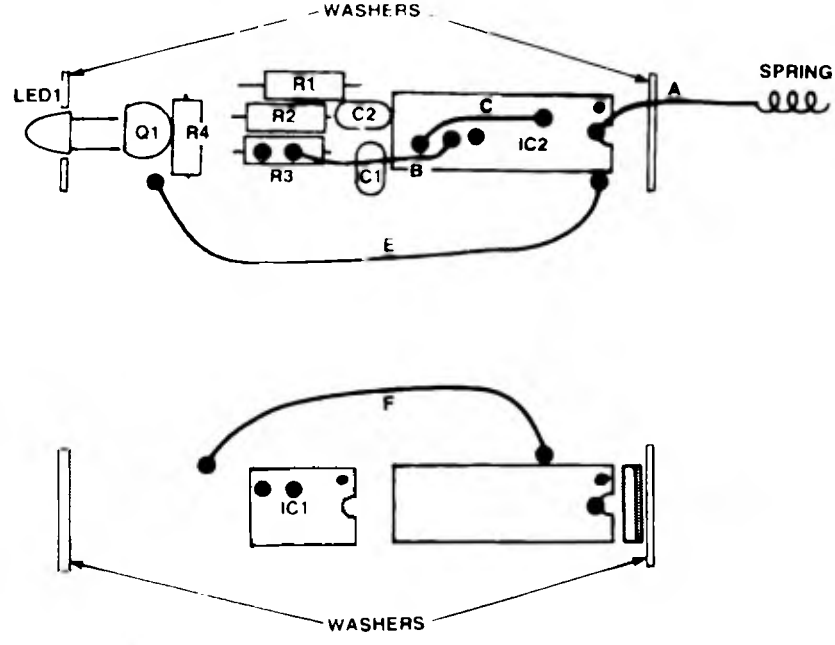


Figure 3. The assembly drawing for the transmitter.



PARTS LIST — ETI-343

Resistors ..... all ¼ W, 1% tolerance
R1, 2 ..... values are optional, see Table 1
R3 ..... 10k
R4 ..... 5k6

Capacitors
C1 ..... 1n resin dipped monolithic ceramic
C2 ..... 18p miniature ceramic

Semiconductors
IC1 ..... LM555
IC2, 3 ..... 4021B
Q1 ..... BC549C
LED1 ..... Red, megabrite 1000 mcd

Miscellaneous
Two brass washers (max outer diameter 13 mm, min diameter for centre hole 5 mm). Half metre of 32G BNS insulated copper wire and a section of light gauge aluminium tube (length 94 mm inner diameter 13 mm). A soft metal spring with coil length about 10 mm long, 2 mm pitch and coil diameter between 5 to 8 mm. One plastic cap and a grommet to fit tightly into the ends of the tube. ETI-343 double-sided pc board. Copper or brass sheet (30G) about 60 x 4 mm. One 5 mm diameter plastic knob. Mercury batteries are not included here.

Price estimate: $19-$24

multaneously with your construction work:

1) After cutting your 15 tracks to program your code use a meter to make sure the positive and negative rails are no longer short circuiting. Then put one probe of your meter to the ground or Vcc rail and the other to one of the programming pins. Check whether that pad does connect to the ground ('0') or Vcc ('1') as programmed. Then repeat the same checking for the rest of the programmed pads. Make sure that you have the code correct.

2) As mentioned before, every time an insulated copper wire is soldered, make sure it connects the two points as required. This can be confirmed by checking the resistance between the two points joined by the wire.

3) Be careful not to let the pins of the LED touch the washer. And make sure the polarity of the LED is correct when you solder it on.

4) Give a little pull on the washers after you solder them. They should be as firm as a mountain.

5) There are several tracks right on the edge of the pc board. When inserting the pc board into the aluminium tube, those tracks should not be touching the inner wall of the tube. If they do, a strip of sticky tape on both edges of the pc board will insulate the tracks from the tube.

6) You need four mercury batteries piled up in order to give you enough voltage. They are the same kind of battery you use in a calculator. The body of the battery is usually the positive terminal and it *must* be insulated from the tube. You can roll the four batteries together with a piece of paper, like rolling a cigarette. Stop the paper from coming loose with a bit of sticky tape. Whenever you change the batteries, don't forget to put the batteries inside the paper tube before you put the whole lot back in.

7) Think before you put the batteries in. Wrong polarity will destroy your circuit instantly! The spring is supposed to make contact with the *positive* terminal and the washer at the end of the pc board is to the *negative* terminal of the battery.

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OPTICAL CAR ALARM SWITCH

Part 2

This forms Part 2 of our sophisticated car alarm update project. It describes the switch receiver and installation into your vehicle, after which you should have instant alarm deactivation at your will

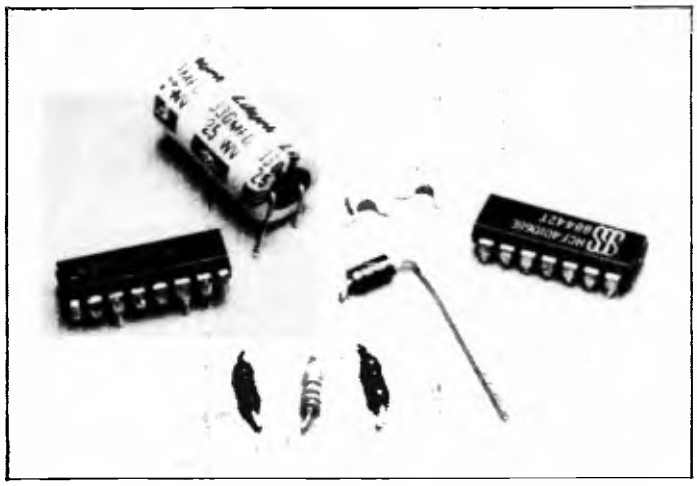
S. K. Hui

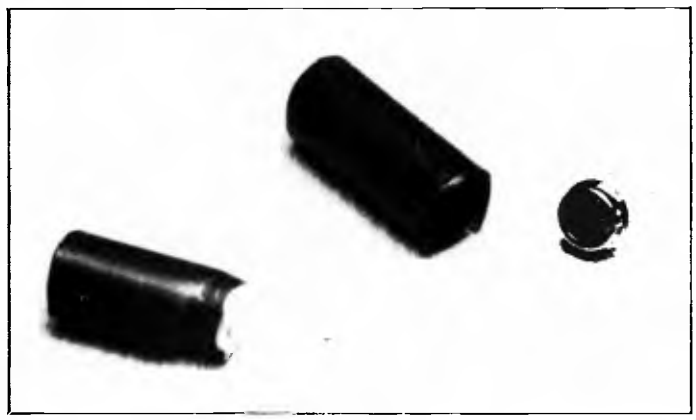
IF BUILDING THE first part of this project (the transmitter) was a nightmare you can be assured that no more fiddly work is required in Part 2, (the receiver).

One of the biggest challenges in this project has been minimising the area of the pc board. To achieve this, good layout design is essential but not sufficient. The biggest obstacle is the wasted space that has to be reserved for the IC pads whether there are tracks going to the pads or not. Once a chip is soldered on, the entire area under the chip on the other side of the board is occupied by the pads. Consequently, no components can use that area.

However, imagine that the pins of the ICs do not (as they usually do), go through a hole on the board to be soldered on the other side, but have their pins cut short and soldered onto pads on the same side of the board, and the area under the ICs on the other side of the board can be occupied by another IC soldered on in a similar manner. Effectively, the board area is doubled.

There has been a lot of talk recently on the use of surface mounting techniques on pc board assembly lines. The biggest gain in using such technique is faster board assembling. In industrial applications, a robot arm can be used to put the components down on to the board effeciently and accurately. For most hobbyists, this technique suffers a fatal draw back, which is that surface mount





Above. The sensing diode on the right should insert into the heatshrink tube to form the fixture on the right.
Left. A display of the semi-surface mount and surface mount components

TABLE 2. ALTERNATIVE TRANSMISSION RATES

Transmission rate	R8	R9	RV1
2519 bit/s	1.5k	6.8k	10k
1412 bit/s	6.8k	10k	20k
7073 bit/s	47k	6.8k	20k

components are far too expensive.

During the design of the transmitter board I was inspired to use the technique of 'semi-surface mounting' with normal components. As the name implies, it is not true surface mounting, however, it has the advantage of using normal, low cost components. The resulting board is very small relative to the number of chips. The tracks are not too thin for ordinary board etching techniques and only a small number of holes need to be drilled.

One small problem is that some of the pins need to be chopped before they are soldered on. Quite often, pins are used as feedthrough wires for joining tracks together so extra care is required when assembling the board.

The design approach of the receiver circuit is pretty standard. It works like the 6850 ACIA mentioned in Part 1, which depends on a local oscillator with its frequency divided down to generate the sampling pulses. The frequency of the oscillator is programmed by a resistor/capacitor network built around a Schmitt trigger. The three optional transmission rates (detailed in Part 1) require three different matching frequencies in the oscillator. Resistances for these frequencies are tabulated in Table 2. For those of you who devised your own transmission rate, instructions and formulae are given to help you to tune your oscillator.

Resistances, capacitances and characteristics of ICs are very much dependent on temperature. This means your well tuned oscillator can quite easily drift out of the workable range. This is important because the temperature inside a car can vary a lot depending on the weather. To ensure reliability, high stability resistors and capacitors are recommended. I have tested the receiver board under extreme temperatures. It worked at 0°C and would probably work below that, however, it stopped working at about 91°C. This was with low quality components so it would be a surprise if a circuit with better components could not better these figures.

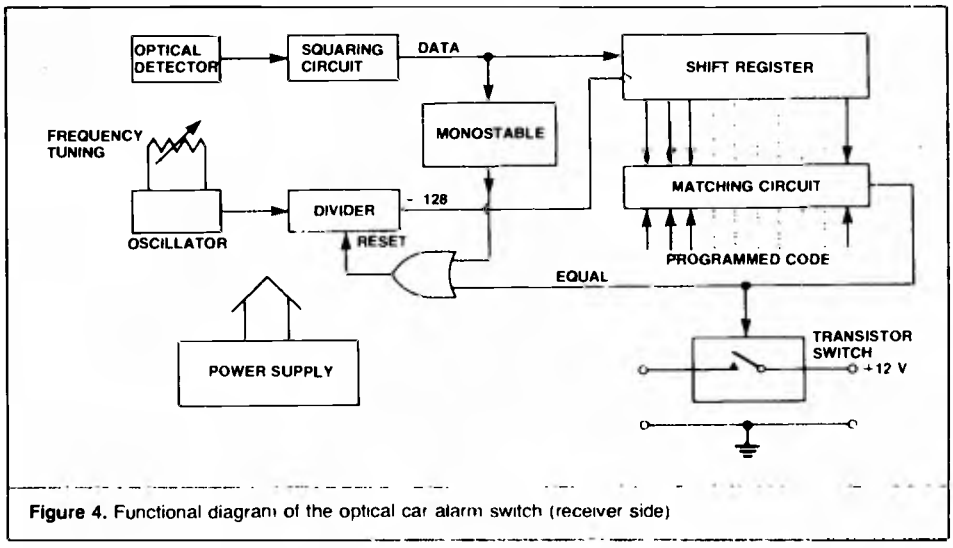


Figure 4. Functional diagram of the optical car alarm switch (receiver side)

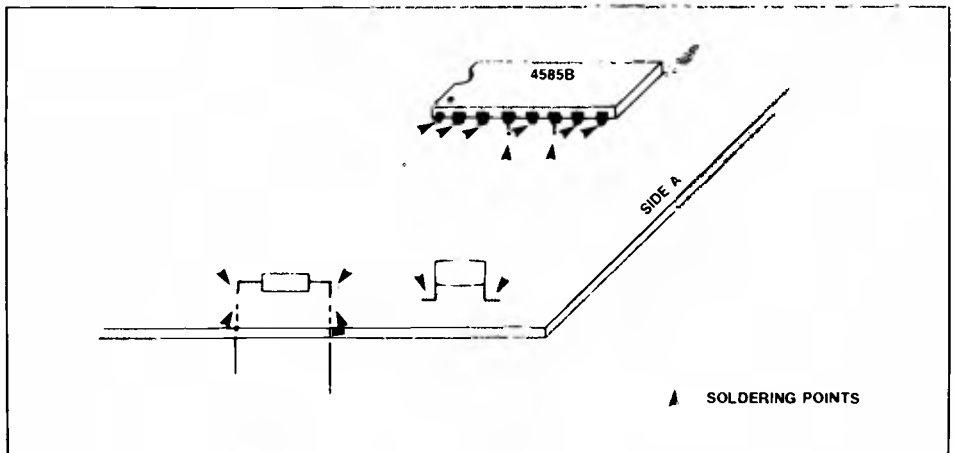


Figure 5. Typical examples of the three different groups of components. Resistor is 'normally' mounted. IC is semi-surface mounted and the capacitor is surface mounted

Design principle

The first thing to look at in the design is the detector (Figure 4). It senses the light falling upon it and amplifies it. The signal is then squared up to true logic levels (1 and 0) by the squaring circuit which is basically a comparator. The output from this section ▶

should be the same as the original wave form when it was first transmitted.

Major design of the circuit is centered on sampling and matching of the code. A tunable high frequency generated by the oscillator is divided by 128. The divided frequency is the same as the sampling frequency. It clocks the shift register and the sampled data from the detector gets passed down the register chain. The 16-bit register, consisting of two 4094 ICs, has an output for each stage which feeds the matching circuit, consisting of four comparator ICs. These comparators continuously match the shift register outputs with the other set of logic signals programmed by you.

When a perfect match occurs, an 'equal' signal is sent back to disable the divider, which stops any further sampling. The whole circuit stays in this condition until it is reset. This same signal is also used to turn off the transistor switch, which in turn, disconnects the 12 V to your car alarm. Without its power supply, the car alarm is disabled, allowing access without false triggering. Most alarms have a flashing LED which indicates their state. If yours doesn't have one, it's a good idea to fit one.

It's necessary to install the optical car alarm switch in such a way that when you start the engine, power to the ETI-343 is cut off. This minimises a lot of false triggering since the car alarm and the optical switch are both off while you are travelling. (As a matter of fact, during testing the ETI-343

HOW IT WORKS — ETI-343

The reverse leakage current through the light sensing diode D1 depends on the amount of light falling on it and the ambient temperature. To minimise the current generated due to the latter factor, its terminals are held to the same potential, ie, short circuited. Since pin 2 and pin 3 of IC1 are both at virtual ground, the voltage generated at the output of IC1 is equal to the product of the leakage current and the 2.2 megohm resistor. Capacitor C1 forms a negative feedback path for high frequencies, thus eliminating any high frequency oscillation in the op-amp. The output signal is then ac coupled to the second stage, a comparator. Any sensor will drift due to age or ambient changes, so dc coupling is obviously not a good solution.

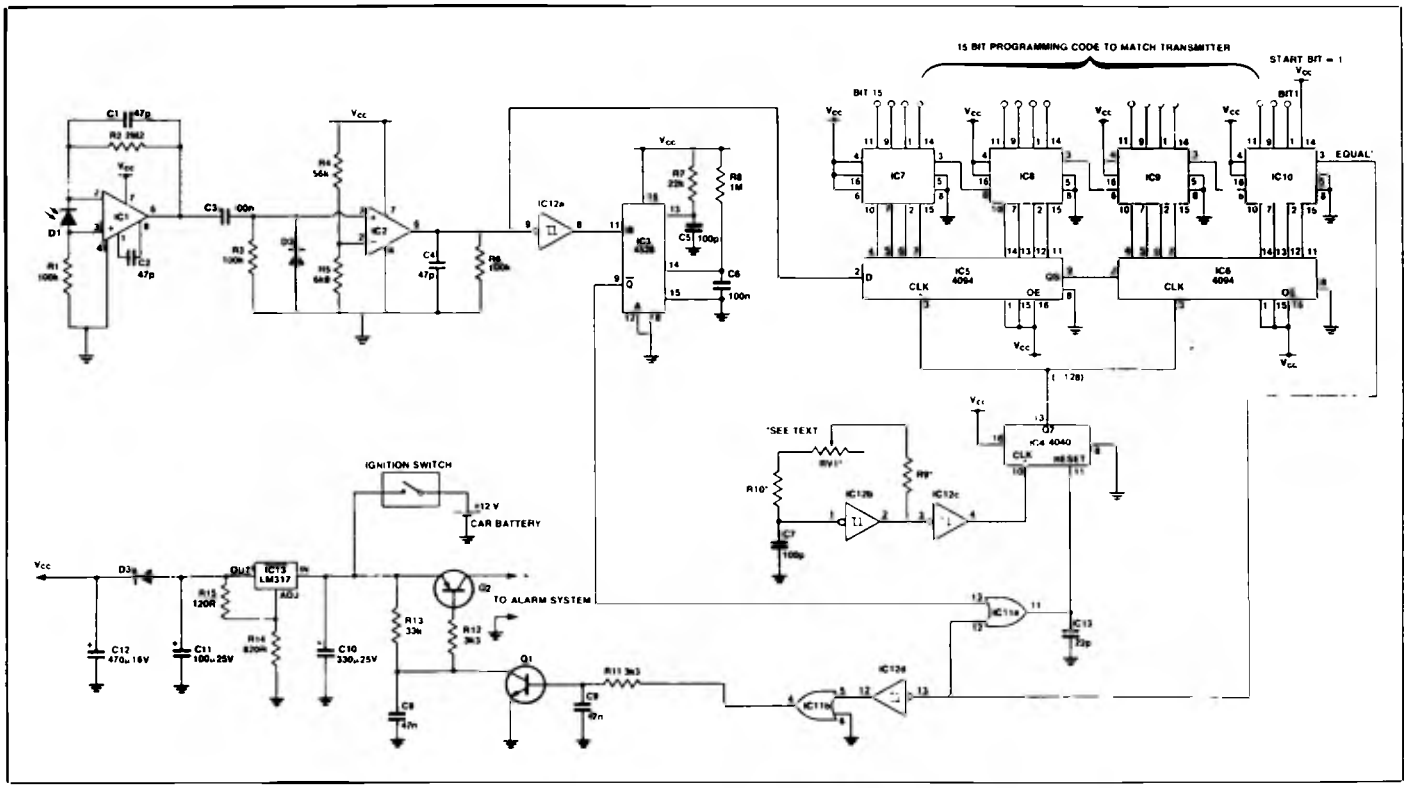
The reference voltage of the comparator is set by R4 and R5. Normally, its output is sitting at 0 V. The first start bit causes the output to go high and, due to the inverting action of IC12a, a negative edge is applied to pin 11 of IC3. This generates an active low pulse to IC11a (pin 13). Normally the 'equal' signal is low (see the schematic pin 12, IC11a), because there isn't a matching code received. Therefore, pin 11 of IC11a goes low and releases the reset pin of IC4. IC4 starts to count the number of clock pulses applied to its pin 10 from the oscillator. For every 128 clock pulses, an active high pulse is generated at pin 13. This is our data sampling pulse. This pulse clocks the data into the registers.

IC5 and IC6 are cascaded into a 16-bit wide shift register. The parallel outputs of the register go into IC7, IC8, IC9 and IC10. They continuously match the register outputs with your programmed code. The 'equal' signal ripples through the four stages matching circuit if the codes are all matched. It goes high and feeds back to pin 12 of IC11a. The OR operation of IC11a allows the active signal to reset IC4 regardless of the state of the monostable (IC3). This disables clocking of the shift register and turns off transistor Q1. Capacitor C8 charges up and turns off Q2, cutting off the 12 V supply to your car alarm. Turning on your ignition key now also cuts off the supply to the ETI-343 circuit.

The oscillation frequency of IC12b is controlled by the total resistance of RV1, R9, R10 and C7. The formula is given by:

$$f = \frac{1}{RC\ ln\ \left(\frac{(V_{CC} - V_{T-})}{(V_{CC} - V_{T+})}\ \frac{V_{T+}}{V_{T-}}\right)}$$

where C (C7) is capacitor value in μF, R the value of R9, R10, RV1 in kohms, f the frequency in kHz, V_{T+}, V_{T-} the threshold voltages and V_{CC} is the operating voltage (9.3 V). Threshold voltages are different for different manufacturers and are affected by operating voltage and temperature. R is the total resistance of RV1, R8 and R9. For any transmission rate that you are using, the golden rule is: the frequency of oscillation must be equal to 128 x 2 x your chosen transmission rate. Table 2 shows the recommended values for R10, R9 and RV1 for the three transmission rates I introduced in Part 1. The above formula will help if your transmission rate does not fall into any of these.



PARTS LIST — ETI-343

Resistors ..... all metal film, ¼ W, 1% unless noted
- R1, 3, 6 ..... 100k
- R2 ..... 2M2, carbon film
- R4 ..... 56k
- R5 ..... 6k8
- R7 ..... 22k
- R8 ..... 1M
- R9, 10, RV1 ..... (see values in Table 1)
- R11, 12 ..... 3k3
- R13 ..... 33k
- R14 ..... 820R
- R15 ..... 120R

Capacitors (all resin dipped mono-ceramic unless noted)
- C1, 2, 4 ..... 47p
- C3, 6, 14, 15, 16, 17, 18, 19 ..... 100n
- C5, 7 ..... 100p
- C8, 9 ..... 47n
- C10 ..... 330µ, 25 V, electro
- C11 ..... 100µ, 25 V, electro
- C12 ..... 470µ, 16 V, electro

Semiconductors
- IC1, 2 ..... CA3130E
- IC3 ..... 4528B
- IC4 ..... 4040B
- IC5, 6 ..... 4094B
- IC7, 8, 9, IC10 ..... 4585B
- IC11 ..... 4071B
- IC12 ..... 40106(SGS)
- IC13 ..... LM317 (TO220)
- Q1 ..... BC549C
- Q2 ..... BD140
- D1 ..... BPW21
- D2 ..... 1N914
- D3 ..... 1N4001

Miscellaneous
A double-sided pc board; mica, screws and nuts for IC13 insulated mounting; hookup wire; thermal heatshrink 10 mm diam, 30 mm long.

Price estimate: $68

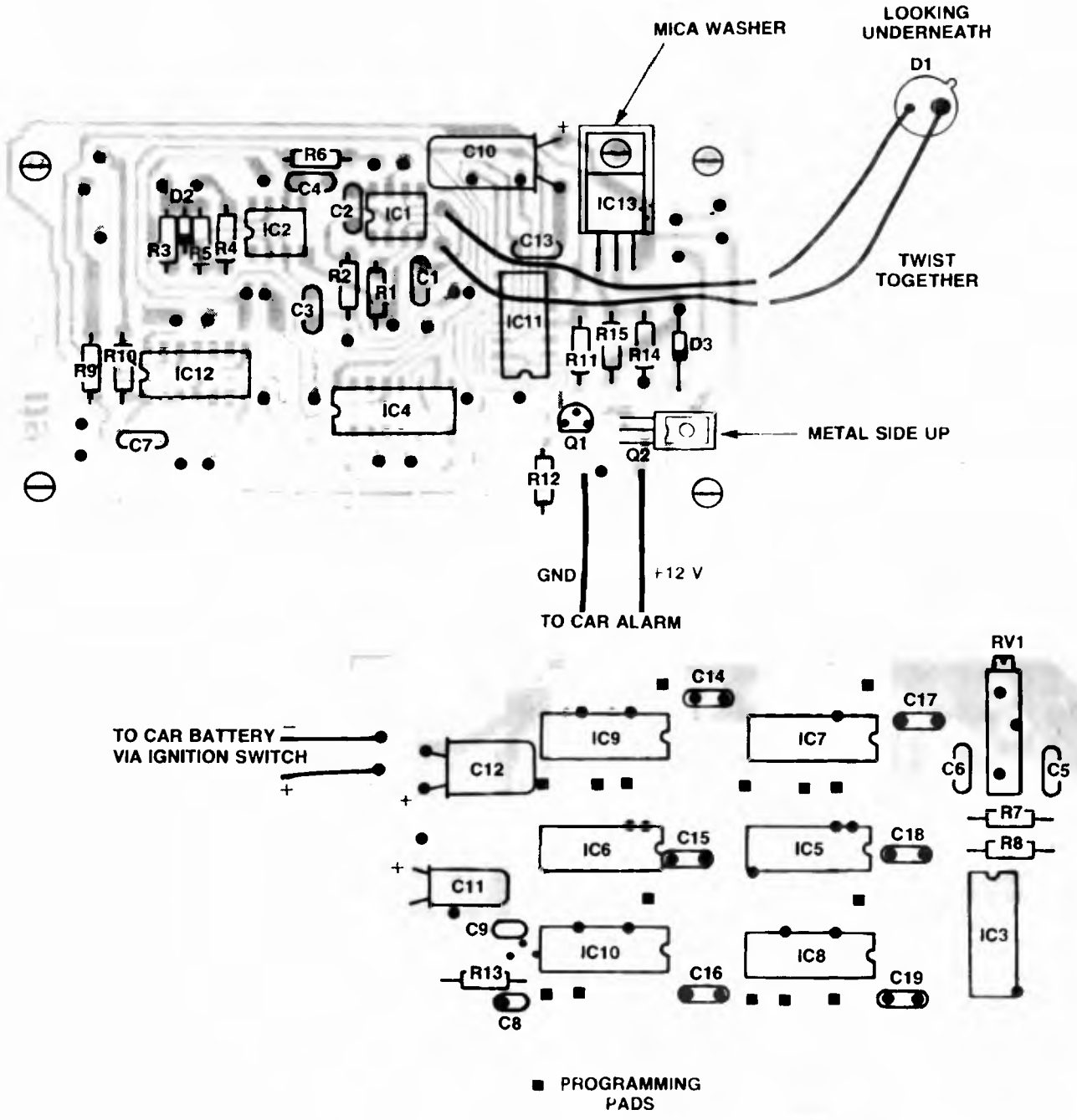


TABLE 3a. COMPONENT MOUNTING METHODS

	Surface Mount	Semi-surface Mount	Normal Mount
ICs	1, 2, 4, 11, 12, 13	3, 5, 6, 7, 8, 9, 10	none
Transistors	Q2	none	Q1
Capacitors	1, 2, 3, 4, 5, 6, 7, 9, 11, 13	8, 10	12, 14, 15, 16 17, 18, 19
Resistors	1, 2, 3, 4, 5, 6, 7 8, 9, 10, 11, 12, 13, 15	14	none
Diodes	D2	D3	none

did not give one false trigger while the car was moving, even when it was 'on'.)

Turning off the engine should energise the switch, thus connecting the 12 V back to your car alarm system immediately. Of course, an exit delay has to be allowed, otherwise you would trigger the alarm as soon as the engine was turned off. Read the construction section for more on entry exit delays.

The receiver oscillator is free running, regardless of other signals, and is fed to by the divider, which is normally reset. The divider is controlled by a monostable. Upon reception of the first start bit, the monostable is activated, and its output releases the divider which outputs a pulse after 128 clock pulses from the oscillator.

The monostable is arranged in a resettable mode with a 100 millisecond timing period. Timing starts as soon as the first start bit activates it. Before the 100 milliseconds expire, any other 1s in the code stream will refresh the timing period back to 100 milliseconds. That is, so long as the transmission continues, the received 1s will keep the monostable and the divider active. When the transmission stops, the monostable times out after 100 milliseconds and resets the divider. No more sampling is allowed, and the circuit goes back to the listening mode.

Recall that the matching circuit is continually matching the two sets of codes, one from the shift register, which is sliding across the other set, fixed by programming. If, at any instance, the two sets match, an 'equal' signal is sent to stop the divider.

The power supply section is designed around the LM317 regulator. Since the output voltage affects the oscillator frequency, high stability resistors must be used to program the regulator output voltage. Another point to notice: CMOS chips with the same number sometimes don't have the same characteristics. Take for example the 40106B Schmitt inverter, where threshold voltages differ from manufacturer to manufacturer. An SGS brand 40106 *must* be used in this project. Anyone who is doubtful should refer to the article 'Some CMOS circuits don't always work' in ETI July 83.

Construction and installation

Construction of the circuit is basically assembling the pc board; there is no fancy box to fiddle with and there is no front panel to drill. Perhaps I should be fair and mention the hidden overhead — installation of the

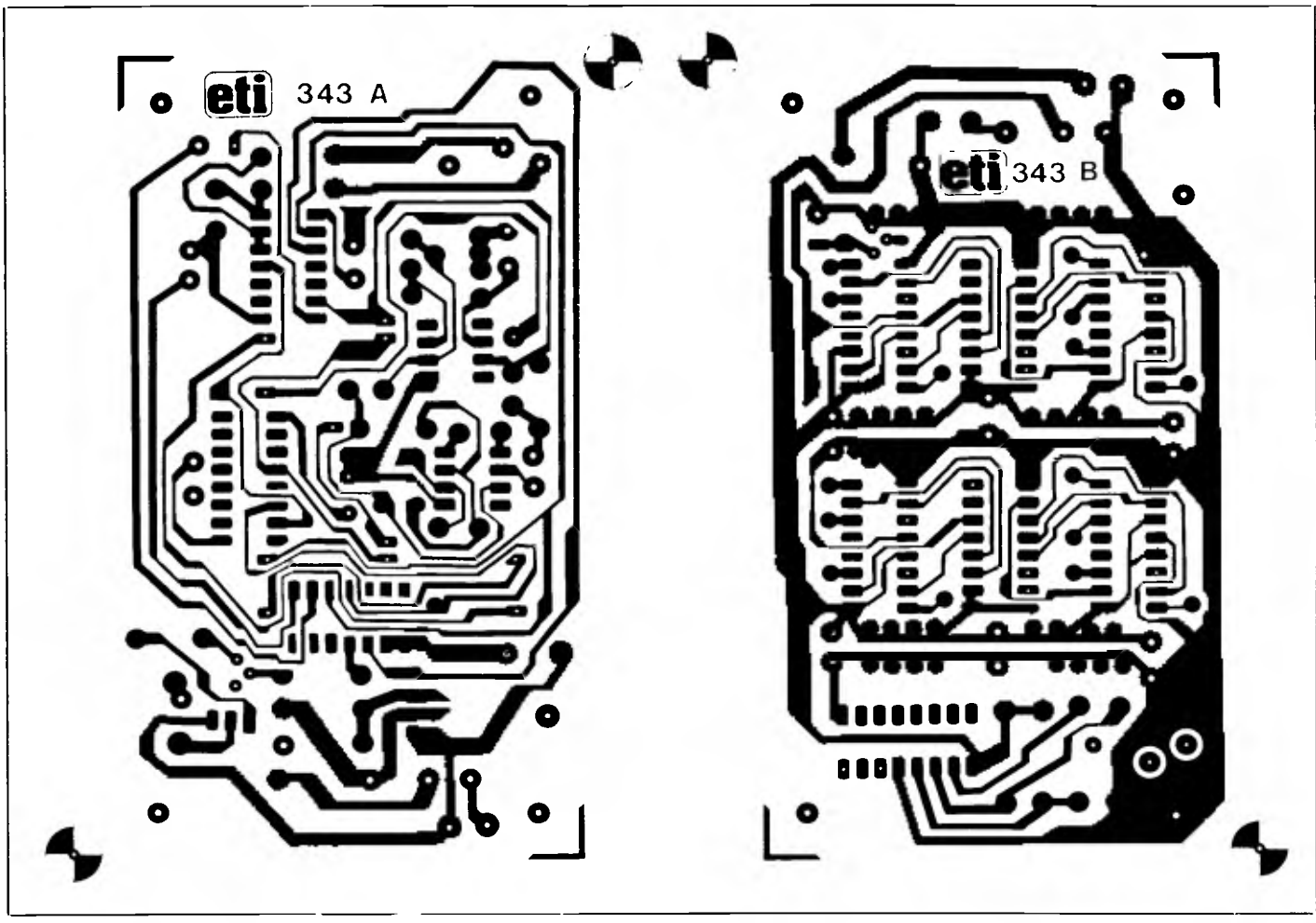


TABLE 3b. IC PINS RESERVED

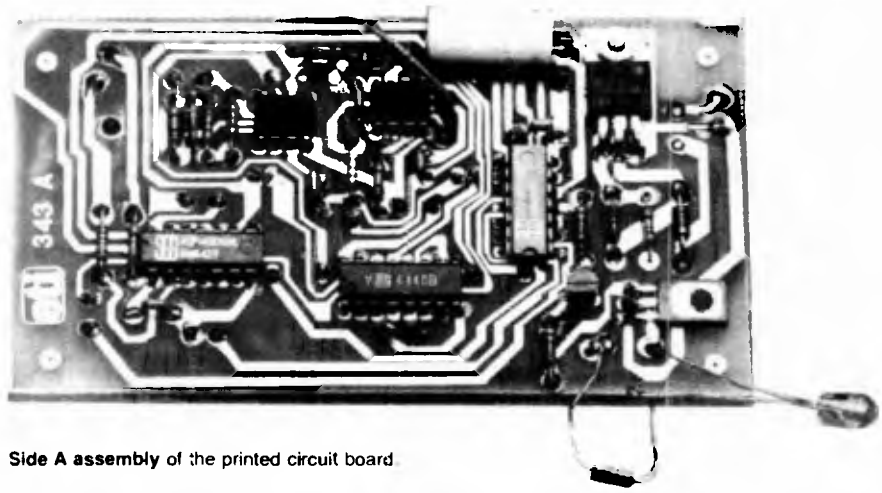
ICs	Uncut Pins	Cut Pins
1, 2, 4, 11, 12, 13	—	all
3	8, 11	all remaining
5	2, 3, 9	all remaining
6	2, 3	all remaining
7	3	all remaining
8, 9, 10	3, 6	all remaining

unit. Don't panic, it is a natural consequence of building any car projects.

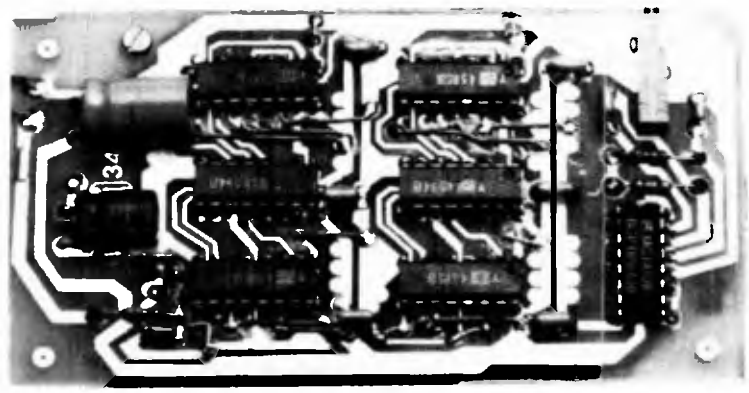
If you are an experienced hobbyist, you will find that the way the pc board is assembled here is slightly unusual. The ways in which the components are soldered onto the board can be classified into three groups: surface mount, semi-surface mount, and the normal mount. Components belonging to the first group have all their pins chopped to the right length and soldered directly onto the pads (see Figure 5). The second group of components have some of their pins chopped and soldered on to the pads; the rest are done in the usual way. For example, all the pins of IC5 are chopped and soldered using the surface mount technique except pins 2, 3 and 9. These should go through holes on the pads and be soldered on to the other side of the board. As the name implies, the components from the normal mount group have all their pins going through holes on the board.

Table 3 displays the classification of all the components in this project. It looks easy but you have to be very careful before you put the components on the board. Cutting the wrong pin simply wastes a component. You may be delighted to hear that no feedthrough wires are used. Well, strictly speaking, they are, but all of them are just the pins of components, and are used to join tracks together on both sides of the board. Therefore, whenever a pin goes through a hole on the board, don't forget to check whether it has to be soldered on both sides or not. The general rule is simple. Any side with a track connecting the pad requires that side of the pad to be soldered on the pin.

Everyone knows that when the ignition key is in the 'on' position, power supply (12 V battery) is connected to things like the radio or cigarette lighter in your car. Turning it to the 'off' position simply turns everything off. The ETI-343 has to be installed exactly the opposite way. This is quite possible because turning your ignition key is in fact turning a multi-tapped switch. The switch provides complementary terminals very much like a double pole relay with normally open and normally close contacts. The wires already connected to the existing alarm are probably the ones that you are trying to connect. Disconnect them from your alarm and connect them to the ETI 343 circuit as shown on the overlay. If you are a greenhorn in cars, an auto electrician should be consulted.



Side A assembly of the printed circuit board.



Side B assembly of the printed circuit board.

Car alarms normally have separate controls for entry and exit delays. Simply adjust the entry delay to minimum, or, if possible, to instant, and leave the exit delay alone. Other products have one control over the two delays plus an instant alarm input. In such cases, do not adjust the delay time but reconnect the wires from the delay input to the instant input to your alarm.

The reed switches and sensors that detect the opening of the boot or the bonnet are usually connected to the instant input. Sensors to detect the opening of the doors are usually to the delay input. All you have to do is to connect all the sensors to the instant input. Since exit delay is unchanged, you can leave the car at your usual pace.

The light sensing diode works best when it is in the dark. To avoid sunlight shining on it directly, the sensor is put into a short section of black thermal heatshrink tube, in much the same way as the lens hood of a camera shields the lens. The sensor is mounted somewhere conveniently close to the window (see the photograph). Wires connecting the sensor to the motherboard should be twisted and made as short as practically possible. The motherboard can

The sensing diode (with spaghetti) should be mounted right behind the window for easier operation.

▶

be hidden inside the dashboard or somewhere near your car alarm.

Testing and setting up

When you have finished building the board, as usual, check the resistance between the positive and negative rails. If the resistance is too low, you'd better check the polarity of all the diodes, electrolytic capacitors and the ICs. If the resistance is OK, you can connect a normal red LED in series with a 470 ohm resistor to the collector of Q2 and ground. The LED is a temporary load while you are testing the circuit on the bench. See Figure 6 for the connection. Now connect the 12 V battery to the circuit and the LED should light up.

Turn RV1 clockwise until you can hear a clicking noise. RV1 is now at its minimum resistance. Turn on your transmitter a few centimetres away from the sensor. If the dummy load (LED) does not turn off, stop the transmission and turn RV1 anti-clockwise (increasing resistance) by a small amount. Turn on the transmitter again to see whether the dummy load is triggered. If not, repeat the same procedure until it does trigger. RV1 now has the minimum workable resistance. Unsolder RV1 carefully without touching the tuning screw on it. Measure the resistance between the middle pin and its nearest pin. Note the resistance and carefully solder it back on to the board. The idea is to repeat the same procedure until the maximum workable resistance is found, then the resistance of RV1 is set back half way between the two, giving you equal tolerances against positive and negative drift in the oscillator.

To find the maximum workable range, first turn RV1 anti-clockwise fully until the clicking noise is heard. Reset the circuit by disconnecting the battery. Due to the high protection on board against voltage spikes, the circuit does not reset immediately on disconnecting the power. It requires 40 seconds or more. You can, if you are impatient, short circuit the positive and the negative rails on the board with a piece of wire *after* the battery has been disconnected. Now connect the battery back to the circuit and the dummy load should light up. Turn the transmitter on and see whether the dummy load gets turned off. If not, adjust RV1 clockwise slightly (decreasing resistance) and turn on the transmitter again. Repeat the procedure until the dummy load triggers. As before, unsolder the pot carefully and measure its resistance. This is your maximum workable resistance. Set the resistance half-way between the two and solder the pot back.

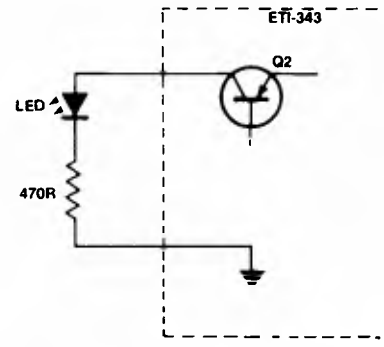


Figure 6. Temporary load for testing.

If nothing happens over the whole range of RV1, debugging time has begun! Check pin 6 of IC1 to see if pulses are there when you transmit signals to the sensing diode (D1). If not, it is most likely due to the wrong polarity of D1. Check pin 6 of IC2. Full digital pulses should appear there. As soon as you transmit, voltage at pin 9 of IC3 should go low and clock pulses should appear on pin 3 of IC5 and IC6. Pin 4 of IC12 shuld be oscillating all the time. Normally, pin 3 of IC10 is at low. It goes high when the correct code is received. If a high on this pin does not turn the dummy LED off, check the pins of Q1, Q2, or even the polarity of the dummy LED. ●

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STEREO CHORUS ENSEMBLE

Fatten up your keyboard or guitar sounds with this multiple image chorus unit. Its in stereo too!

Terry Kee

The chorus effect is probably familiar to most musicians. It produces an effect of sound being emitted in harmony from a multiple source, hence the word 'choral'. It can be used with synthesizers notably of the digital sort, which have string voices that sound very 'unstring'. In this application the chorus unit really does enhance the effect, making it sound much smoother and realistic. Guitar sounds also sound creamier and richer. The stereo effect enhances the chorus effect further and adds an extra dimension to the sound image.

Description

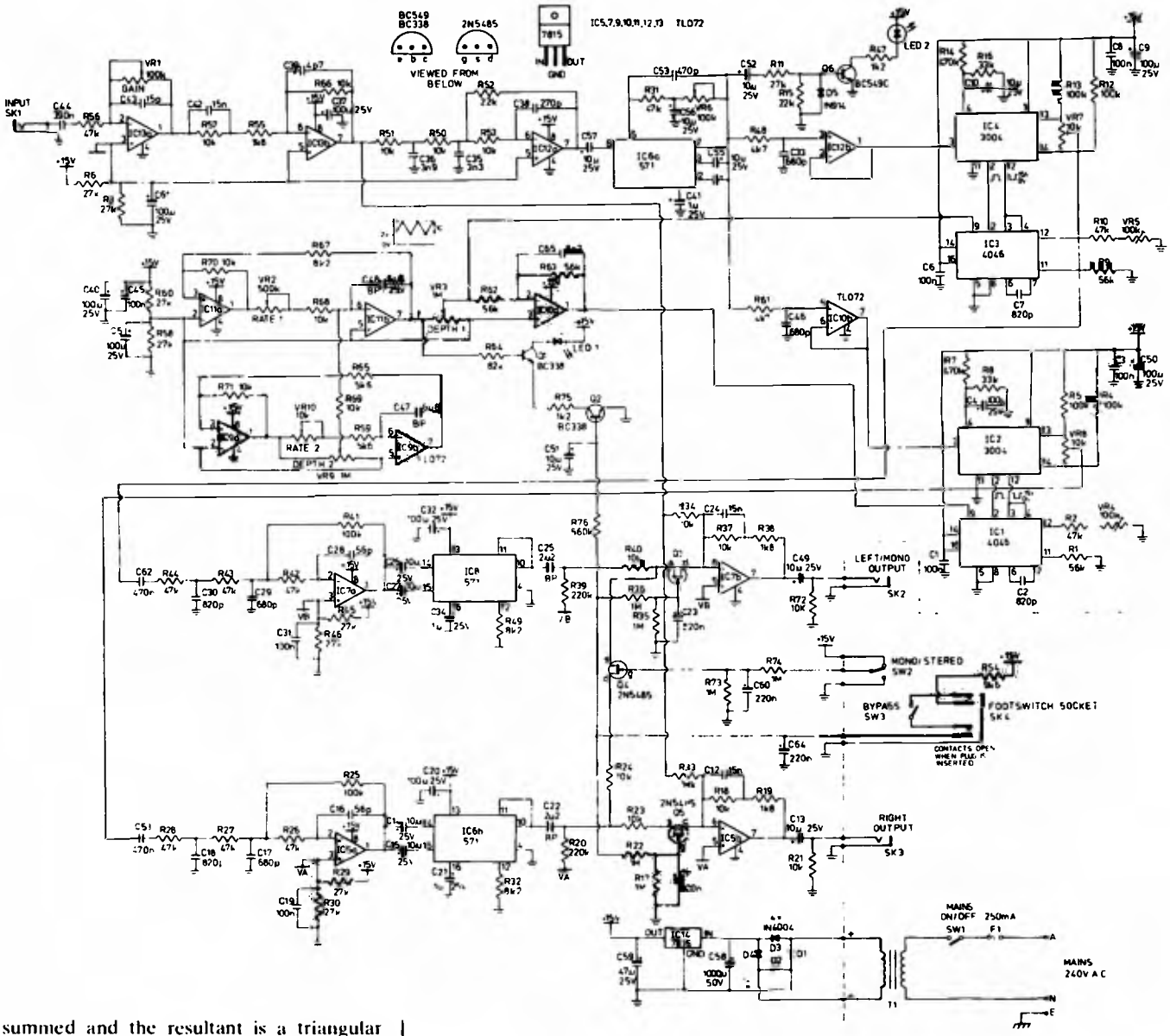
The unit converts a mono signal source to stereo. It is a true stereo device in that 2 completely separate delay channels are used. The delay times are modulated in anti-phase so that when one delay line is at maximum delay the other is at minimum and vice versa. The unit is also unusual in that it has a modulation facility to enhance the choral effect. The chorus effect is obtained by varying the delay time of the delay line, around 10 mS, and adding it to the original signal. The result is a signal with notches in it's response that are swept up and down in frequency. Bucket Brigade Devices (BBD's) are used to delay the signal.

For musical applications the major problem with BBD's is that they are inherently noisy devices. In this unit the problem is attacked by incorporating companding to boost input low level signals out of the noise floor of the delay line and perform the complimentary actions at the output to restore the original levels. Pre-emphasis and de-emphasis reduces the noise even further. The block diagram shows the general outline of the unit.

The signal in the BBD is sampled at a rate determied by the clock generator. To prevent aliasing from occuring the sampling frequency has to be at least twice the maximum bandwidth of the input signal. There is a further consideration in that for minimum distortion through the MN3004 the bandwidth of the input has to be about a third of the sampling frequency. The input low pass filter limits the bandwidth to about 9 kHz so the minimum frequency is limited to about 24 kHz. This corresponds to a maximum delay of 10 mS. The signal is buffered to ensure that the 2 channels are separated to keep clock intermodulation whine and whistles to an absolute minimum. The buffered signals are then fed to the BBD's in the left and right channels.

Because of the limited signal voltage swing of 1.8 Vrms through the MN3004 care must be taken not to overload the device. To help the user set up the correct levels for maximum performance, a level LED is designed to start turning on at about 0 dB, leaving a further 5 dB headroom before clipping commences. Extraordinary care was also taken to keep the power supply rails squeaky clean, hence the use of all the decoupling capacitors. HF circuitry was physically separated from the audio path as far as possible.

The voltage control clock generators for both channels are set to approximately the same range of frequencies however they are modulated in anti-phase. This means that when one is at maximum frequency the other is at minimum frequency, producing minimum and maximum delay times respectively. The clock frequency range is roughly between 24 kHz and 100 kHz. The modulation range can be set internally. The VCO clock generators are modulated by 2 low frequency triangular oscillators of which both the frequency and amplitude can be varied by controls on the front panel. The outputs are



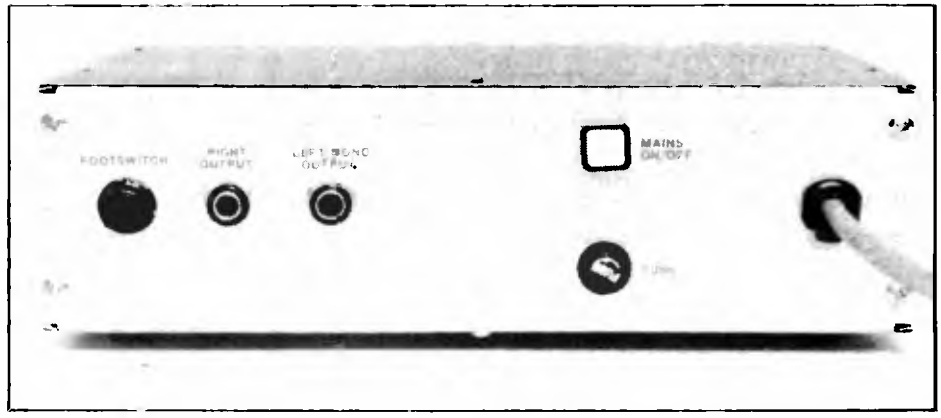
summed and the resultant is a triangular waveform with a high frequency superimposed on it. The effect of such a waveform is that the stereo image pan rate is determined by the lower frequency waveform and the apparent multiple imagery by the faster one. An inverter inverts the output to drive the clock generators in anti-phase. The depth 1 control varies the overall modulation level.

The delay line outputs are then fed to their respective low pass filters which smoothes out the sampled signal and filters out the clock components. After expansion the audio is passed through a FET switching network, which allows the chorus effect to be switched in or out. As an option a remote footswitch can be plugged in to bypass the switch on the front panel. DC switching voltages are used throughout to minimise hum and noise pick-up. A mono/stereo switch allows the output of the delay lines to be added together to give a similar chorus effect without the stereo imagery. The mono output is made accessible at the left output.

Construction

The project is built on a single-sided pc board. Start by inspecting the pc board for any broken or bridged tracks. Once you are satisfied that the pc board is perfect the links, resistors, capacitors and presets can be mounted and soldered in. Take care with the correct orientation of the electrolytics. The use of a finely tipped soldering iron is recommended as some of the pads are quite close to tracks.

The ic sockets comes next. Note that all the ic's face the same direction. Leave the ic's out for the moment. Next insert the transistors, regulators, FET's and diodes making sure of their correct orientation.



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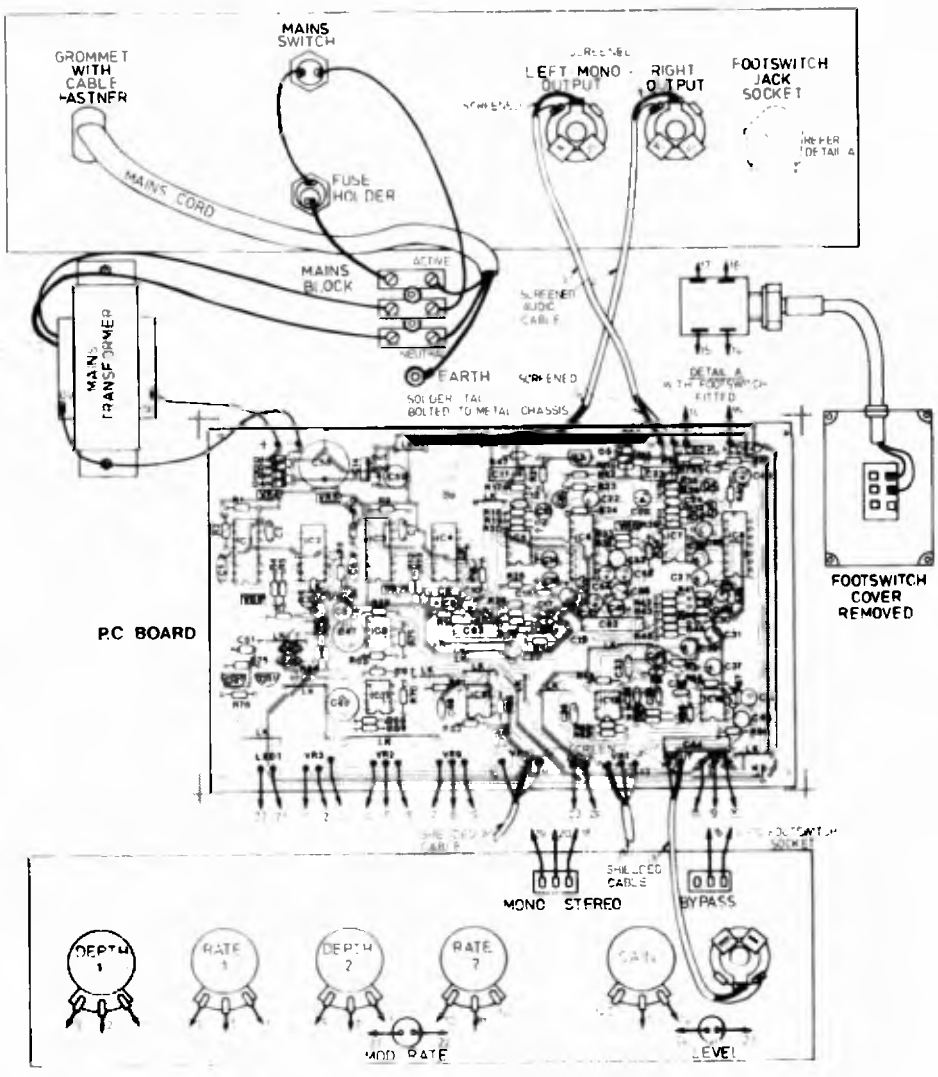
Use the scotchcal as a template and align it so that the corners square up. Mark the centres of the holes with something sharp like a drill bit, then take the template off and drill the holes. Do the same for both the front and back. Use a reamer to open the holes to the correct diameter. Drill the holes for the pc board, mains block, earth tag and transformer. Mount the transformer as far away from the audio inputs as possible to minimise hum pick-up. Note that the earth tag has to be bolted down onto the metal chassis of the box.

Clean the front and back panel before sticking down the scotchcal panels. Cut the holes out with a sharp knife or scalpel. Next cut the pot shafts to a length to fit your knobs and mount them along with all the sockets, switches, mainsblock, fuseholder and transformer.

The mains cord should enter the box via a rubber or plastic grommet with an anchor clamp. The Active and Neutral connections should be terminated into a mainsblock. Refer to the wiring diagram. Solder the Earth wire directly to the earth tag on the chassis. It's a good idea to tin the mains wire with solder to ensure a good solid contact. Next wire in the fuseholder, mains switch and transformer.

REAR PANEL



FRONT PANEL

Parts List

Resistors
All ¼ W Metal film, 1% unless stated otherwise
R1,9 ..... 56k,5%
R2, 10, 56 ..... 47k, 5%
R4, 5, 12, 13 ..... 100k, 5%
R7 ..... 470k, 5%
R8 ..... 33k, 5%
R20, 39 ..... 220k, 5%
R21, 31, 34, 68, 69, 70, 71, 72 ..... 10k, 5%
R32, 49, 67 ..... 8k2, 5%
R47, 75 ..... 1k2, 5%
R54, 59, 65 ..... 5k6, 5%
R64 ..... 82k, 5%
R76 ..... 560k, 5%
R3, 6, 11, 29, 30, 45, 46, 58, 60 ..... 27k
R14 ..... 470k
R15, 52 ..... 22k
R16 ..... 33k
R17, 22, 35, 36, 73, 74 ..... 1M
R18, 23, 24, 33, 37, 40, 50, 51, 53, 57, 66 ..... 10k
R19, 38, 55 ..... 1k8
R25, 41 ..... 100k
R26, 27, 28, 42, 43, 44 ..... 47k
R48, 61 ..... 4k7
R62, 63 ..... 56k
VR4, 5, 6 ..... 100k 5mm vertical miniature trimpot
VR7, 8 ..... 10k 5mm vertical miniature trimpot
VR1 ..... 100k log pot
VR2 ..... 500k linear pot
VR3, 9 ..... 1M log pot
VR10 ..... 10k linear pot

Capacitors
C1, 6, 19, 31, 45 ..... 100n greencap
C2, 7, 18, 30 ..... 820p ceramic, 10%
C4, 5, 9, 20, 32, 37, 40, 50, 61 ..... 100µ/25V pc mount electro
C8, C3 ..... 100n miniature ceramic
C11, 23, 60, 64 ..... 220n/35V tantalum
C12, 24, 42 ..... 15n greencap
C10, 13, 14, 15, 26, 27, 49, 51, 52, 54, 55, 56, 57 ..... 10µ/25V pc mount electro
C16, 28 ..... 56p ceramic 10%
C17, 29, 33, 46 ..... 680p ceramic 10%
C21, 34, 41 ..... 1µ/25v pc mount electro
C22, 25 ..... 2µ2/25V Bipolar electro
C35 ..... 3n3 greencap
C65 ..... 8n2 greencap
C36 ..... 3n9 greencap
C38 ..... 270p ceramic 10%
C39 ..... 4p7 ceramic 10%
C43 ..... 15p ceramic 10%
C44 ..... 390n greencap
C59 ..... 47µ/25V pc mount electro
C62, 63 ..... 470n greencap
C47, 48 ..... 6µ8/25V Bipolar electro
C53 ..... 470p ceramic 10%
C58 ..... 1000m/50V pc mount electro

Semiconductors
IC1, 3 ..... 4046 Phase lock loop
IC2, 4 ..... MN3004 512-Stage BBD
IC5, 7, 9, 10, 11, 12, 13 ..... TL072 Dual Op-Amp
IC6, 8 ..... 571 Companding IC
IC14 ..... 7815 Regulator
D1 to 4 ..... IN4004 Rectifier Diodes
D5 ..... In914
Q1, 2 ..... BC338
Q6 ..... BC549C
Q4, 5, 3 ..... 2N5485 N-Channel FET

Miscellaneous
T1 ..... 0-15V transformer at 1A
F1 ..... M205 Panel Mount Fuse holder and a 250mA fuse
SW1 .. Push button on/off switch rated at 240VAC
SW2, 3 ..... Miniature toggle switch SPDT
SK1, 2, 3, 4 ..... 6.5mm Mono Insulated Jack Socket (contacts closed when plug is not inserted) IC sockets, mains cord, heavy duty footswitch suitable diecast box for foot switch, metal cabinet (Horwood cabinet 203 x 102 x 254mm) or similar.

Price estimate $158 (includes cost of power supply and cabainet but excludes the optional footswitch). The MN3004 BBD's are available from Radio Spares, 6c Durdans Avenue, Rosebery, 2018, NSW.

Only use suitable 240 Vac cable for all mains connections. Cover all exposed wiring with suitable heatshrink sleeving. Be extra careful with mains wiring, recheck your work. LIVE WIRES CAN KILL.

Use audio screened cable for the input and output connections. Keep the input wire as short as possible to avoid pick-up. Use a short length of twin screened cable to connect in the Rate 2 pot. Cut off the screened wire at the pot end. The rest of the wiring can be done with hook-up wire. Refer to the wiring diagram.

Any suitable rugged box can be used to house the footswitch. I used a small die-cast box (110 x 60 x 30mm) with a 5m length mains cable terminated in a mono jack plug.

Testing

Start by checking the pc board for dry joints and especially for solder splashes across adjoining tracks. Before the unit can be fired up properly the voltages rails need to be tested. Without any of the ic's inserted check that the dc voltage is within 500mV of 15 volts. Do not forget to put in a 250mA fuse into the fuse holder.

Once the correct voltages has been established switch off the power and wait unti C58 has discharged before inserting the ic's. Take the usual precautions with handling all the MOS devices. The BBD's are particularly electrostatic sensitive devices. Before switching on again check the

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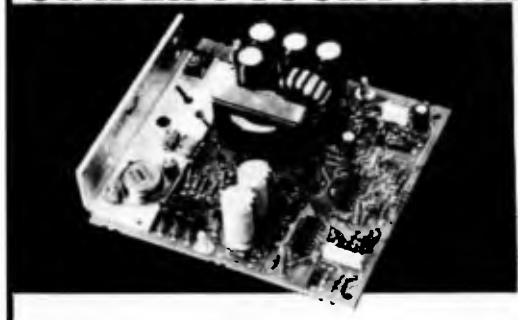

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Selection guide

Model	Input voltage range (DC)	Output voltage adjustment range	Max. current
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3T20AP6115	+10 to +60V	+4.5 to +15V	20A
3T 5AN4030	+10 to +40V	−4.5 to −30V	5A
3T 5AN6030	+20 to +60V	−4.5 to −30V	5A

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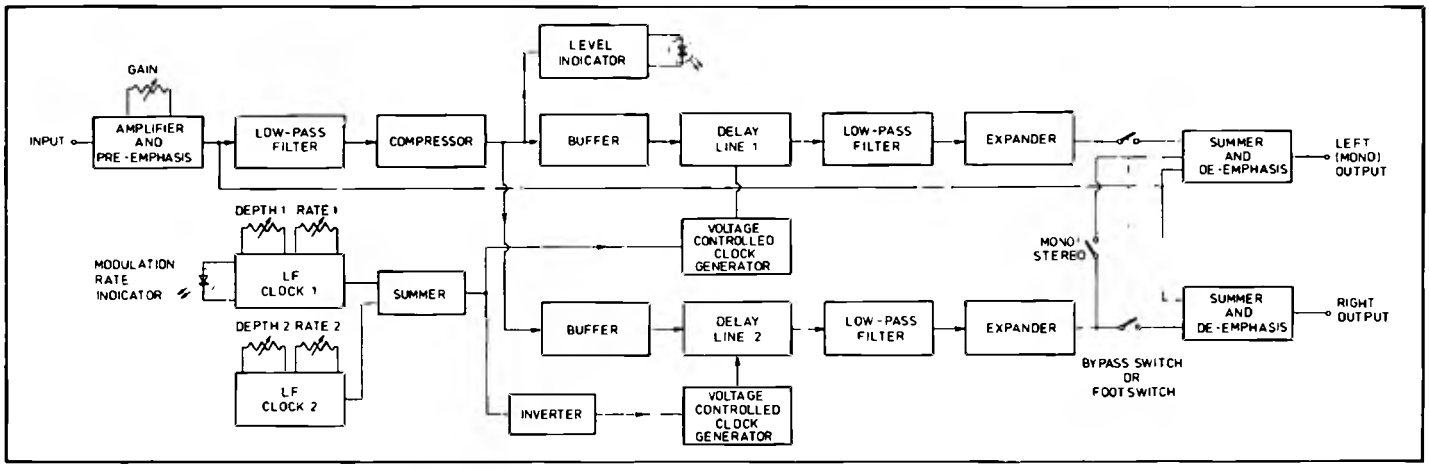


orientation of all the ic's. If everything is okay you should see the modulation LED flashing when the switch on the front panel is switched to the chorus mode.

Set your multimeter to measure dc voltage and with the gain control turned down to the minimum, put the probe at pin 1 of IC12b, adjust VR6 for a reading of 7 volts. This sets up the input dc bias of the MN3004's. Next apply a 500 Hz sine wave and adjust the gain control until the level LED just starts to light up. Put a scope probe at the wiper of VR7 and VR8. You should see a 500 Hz sine wave with a clock signal superimposed on it. Adjust VR76 and VR8 for the minimum clock amplitude. If you do not have access to a CRO then set the 2 presets midway, this adjustment only affects the distortion marginally.

The final adjustment is a personal one. The setting for the deepest chorus effect depends on the type of instrument you intend to use, obviously the harmonic content of a synthesizer voice will be vastly different to a guitar. Plug in the instrument, adjust the gain for a reasonable level and listen to the output. With the unit set to chorus, turn the Depth 1 control to maximum and the Rate 1 control to a fairly slow rate. Turn the Depth 2 control to the minimum and set to the stereo mode while you are doing this test.

A synthesised string voice is a good sound source if you intend to use the unit mainly for keyboards. Play a chord, listen to the left output and adjust VR5 for the smoothest and deepest sweep. Repeat with the right channel except you adjust VR4. Listen to the output in stereo and you should hear the sound swirl from left to right and back again. Good eh! Turning up the Depth 2 control should bring in a slight warble effect. Note that overmodulation will cause a distinct pitch bend particularly when the Rate 1 control is set to the fastest rate. Reducing the overall modulation level via the Depth 1 control will eliminate the pitch bending. It's now up to you to experiment with all the controls.

ETI-1416 HOW IT WORKS

IC13a is configured as an inverting amplifier with an input impedance of 47 k so is capable of accepting keyboards, guitar and line inputs. The gain is variable from full attenuation to a maximum of 6 dB using VR1. The pre-emphasis circuit built around IC13b and associated R's and C's boosts signals above about 1 kHz with a maximum gain of about 14 dB.

The signal is then fed to a 3-pole low pass filter configured around IC12a. It limits the bandwidth to about 9 kHz with an 18 dB per octave slope. Using 1 per cent tolerance resistors helps keep the cut-off frequency within the tolerance of the capicitors, around 10 per cent.

As the circuit is powered from a 0 to 15V supply the op-amps are biased to around 7.5V using resistor potential dividers. One half of IC8 (571) is connected as a compressor with a 2 to 1 compression ratio that is set internally to the device. The resistors R31 and VR6 sets the dc level and is made variable to set the dc bias of the BBD's (IC2 and IC4) to 7V which is the optimum value for the MN3004. The signal is ac coupled via C52 and sent to the level indicator configured around Q6. A resistor pair R11 and R15 divide the signal level to turn Q6 on at about 0dBm. The diode D5 protects the base-emitter junction of Q3 against excessive reverse biased voltages.

The signal is then split to drive the left and right channels. To simplify the circuit description only one channel will be discused. The audio path is buffered by IC12b and along with a low pass filter R48 and C33 prevents hF clock components from getting back into the audio path and causing clock intermodulation noise. The Panasonic BBD (MN3004) requires a 1V dc voltage at pin 4 with a 15V supply and this is supplied via R14 and R16 and decoupled by C10. The output of the MN3004 has a clock null facility provided by VR7, and is used to adjust the clock amplitude to a minimum. IC3 is actually a phase-lock loop (4046) however, only the VCO part is used. As the MN3004 requires an anti-phase signal to clock it, an exclusive or gate internal to the 4046 is used as an inverter. The result is an inverted clock signal at pin 2 of the 4046. With the modulation waveform generated by IC9 and 11, the minimum clock frequency is set to around 24 kHz.

The frequency range can be adjusted by VR5, turning it fully anti-clockwise will give an approximate 24 kHz to 62.5 kHz range and with it fully clockwise will give a 66 kHz to 100 kHz range.

IC10a and b are connected as a simple triangular oscillator. IC10a is configured as a schmitt trigger that drives an integrator IC10b. VR2, R68 and C48 determine the frequency of oscillation and the range is approximately between 0.14 Hz to 7 Hz. The output level can be varied via VR3. The output is inverted by IC10a to produce the anti-phase modulation signal to drive IC1. The second triangular oscillator consisting of IC9a and b is identical to the first one except the frequency range is set between 4.7 Hz to 13 Hz. Again the frequency and amplitude can be varied using VR10 and VR9 respectively. The outputs are summed in IC11b so the Depth 1 control will determine the overall modulation level. Pin 7 of IC11b is also fed to a transistor LED driver Q1 which turns LED 2 gradually on and off at the modulation rate. Q2 is turned on when the chorus effect is selected to be modulated by the oscillator and thus give a visual indication when the effect is switched in.

The output of the MN3004 (IC4) is ac coupled via C62 to a third order low pass filter constructed around IC7a, in order to filter out the clock components of the sampled waveform. The biasing arrangements for the op-amps of the two channels are intentionally separated to minimise clock intermodulation between the two channels.

IC8 is the expander that performs the 2 to 1 complimentary expansion. The signal is ac coupled into pin 14 and 15 of IC8 to improve low level signal tracking. R49 is used to bias the output to 7.5V to maximise the dynamic range. The expander output is then fed to the de-emphasise circuit built around IC7b. It attenuates the signal above about 1 kHz to compliment the pre-emphasis at the input. IC7b also acts as an adder, adding the original pre-emphasised signal from pin 7 of IC13b to the delayed signal. Furthermore the virtual earth junction of IC3b is used for FET switching of the chorus/bypass and mono/stereo mode. The small signal levels across the FETs allows low distortion operation. Switching voltages are 0 to 15V. When the chorus mode is selected Q5 and Q3 are switched on and the delayed outputs are summed in IC7b and IC5b with the original. In the mono mode the outputs of IC8 and IC6b are added together with the original. Both outputs are ac coupled by C49 and C13. The footswitch jack socket SK4 is wired so that when the jackplug is inserted the normally closed contacts are opened and the bypass switch (SW3) on the front panel is bypassed. The circuit draws a dc current of about 45mA.

ETI 287 — LED LIGHT CHASER

THIS PROJECT IS very simple to construct and understand, yet features an immense variety of applications.

When we constructed the prototype it was designed for a two-fold purpose. As well as emulating the "Knightrider" scanner light (a television program featuring a fully computerised state of the art, talking, crime-busting car), it was also used as a bio-medical aid in the learning process of a young, handicapped child.

The useage of this project is limited only by your imagination. In its basic form it is a LED light chaser, but can be used as a normal light chaser by feeding the outputs into transistors, relay's, etc . . . A little experimentation can produce excellent effects, as the well known Melbourne institution "Tikki and John's — Crazyhouse Theatre" have found. They have utilised four of these units to produce an amazing mini light show. A winking, blinking, "computer console" launches an on-stage rocket, the lead astronaut has his own light show on his head, etc. Professional special effects at a fraction of the cost of commercial units.

To keep the project cost-efficient, yet not lose any of the advantages, we opted to use a single-sided printed circuit board and high intensity red LED's. The use of a single-sided board necessitates wire links of tinned copper wire. These are probably the easiest part of the project. The Telefunken SLH56VC high intensity LED's draw the same current and voltage as normal LED's, but are some 100 times brighter. A standard LED produces some 0.9 millicandella (mcd) of light, whereas the SLH56VR emits some 90.0 mcd — ensuring that your chaser can be seen bright and clear at great distances. Current drain on the power supply is minimal. Our prototype ran continuously for well over 100 hours on a standard 9v transistor radio battery.

We found 5mm red LED's to be the most visible and compact, but variations on colour and size are also possible. Another prototype of ours has a mis-matched jumble of colours and looks quite good. If space is not a problem, the new 10mm range has a beautiful, soft, bright red — the best colour in any LED we've ever seen.

The rate of the flash can also be varied.

ETI 287 PARTS LIST

RESISTORS — All ¼ watt unless otherwise specified

R1	330 ohm CR37
R2	56K CR37

POTENTIOMETERS

RV1	1M Vertical Trimpot

CAPITATORS

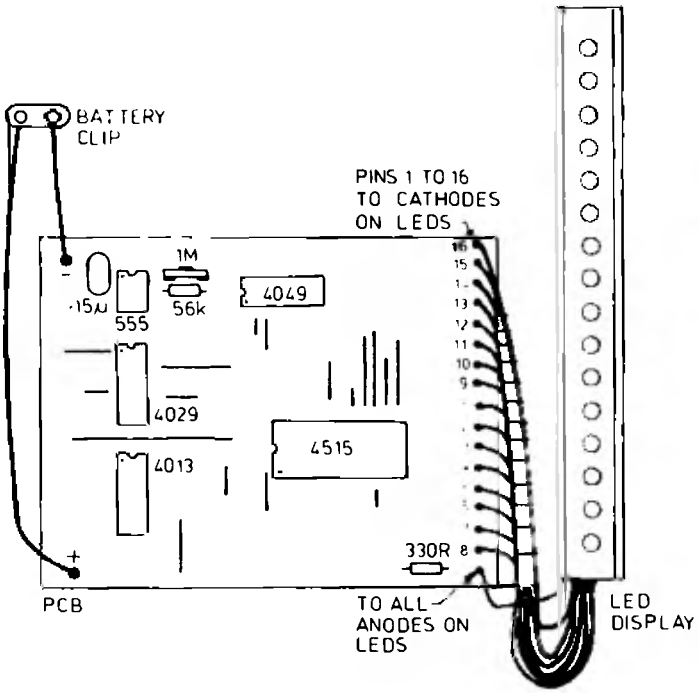
C1	0.15uf (150nf) Greencap

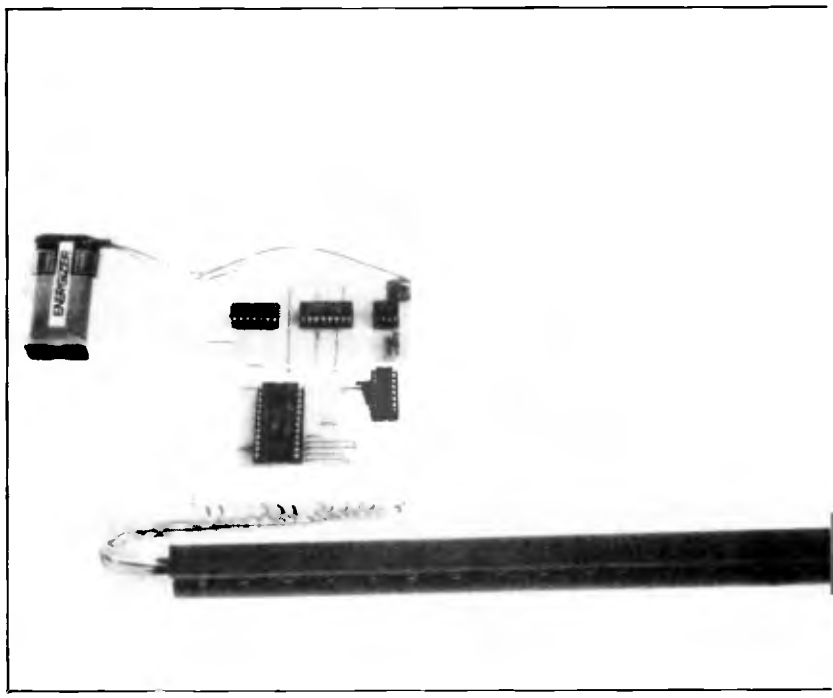
SEMICONDUCTORS

IC1	555 Timer
IC2	4029
IC3	4013
IC4	4049
IC5	4515
LED 1-16	SLH56 VC High-Int. Red LEDs

MISCELLANEOUS

PCB	AEC 86-9-1
Assorted	1 x 9V battery clip, 1 x 8 pin IC socket, 1 x 14 pin IC socket, 2 x 16 in IC socket, 1 x 24 pin IC socket, Tinned Wire, Hook-up wire, Rainbow Cable, Solder.





ASSEMBLY

To begin assembly, check the Printed Circuit Board for bridges, undrilled holes, etc. It is suggested that you use a board for ease and neatness. Cut and shape all wire links, insert, and solder these first. The IC sockets come next, followed by the capacitor, resistors and trimpot.

Solder the output wires to the cathodes of the LED's (or the bases of the transistors if used). Bridge all the LED anodes (or transistor collectors), and solder this bridge to the common rail on the PCB. Insert the IC's, using standard MOS handling procedure.

Note that the 330 ohm resistor may need to be substituted for another value, or left out altogether, depending on the supply voltage. For 9-12 Vdc operation, we found 330 ohm to be adequate. If used in a 12 Vdc supply from a car, a 0.1 uf ceramic or greencap capacitor would be placed across the power in, to avoid a possible "locking in" of all LED's. This is caused by the alternator switching in and out, and resetting the unit. The 1M ohm trimpot can be used to adjust the speed, or rate of flash.

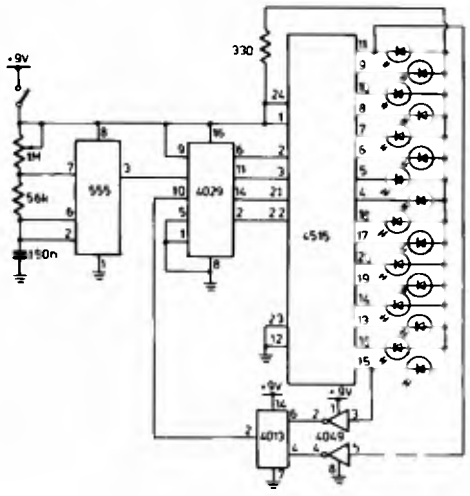
The project is simple to construct but should fault-finding be required, it will probably be due to a simple error, such as bridged tracks on an IC, incorrect orientation of an IC, reverse polarity of a LED, etc. The In-Circuit Digital IC Tester published several issues ago will provide ready check if all IC's — except the 555 timer. ●

This project was devised by the staff at All Electronic Components.

HOW IT WORKS

A 555 timer IC is used for clock pulses, and the trimpot adjusts the rate of oscillation. The output of the 555 — pin 3 — drives the 4029. The 4029 is a BCD up/down counter — its mode depending upon whether pin 10 is high or low. The output of the 4029 is used to drive the input of the 4515; its output being 16 — stage, active on the negative pulse. The function of the 4029 is to invert the pulse coming from the first and last output of the 4515 to either count up or down. Twooutputs of the 4049 are used to set or reset the 4013, sending its output high or low to set pin 10 of the 4029 to either high or low. This forms the stimulus to set the IC to count up or down.

The 330 ohm resistor is used as a voltage drop, and current limiting resistor for the LED's.



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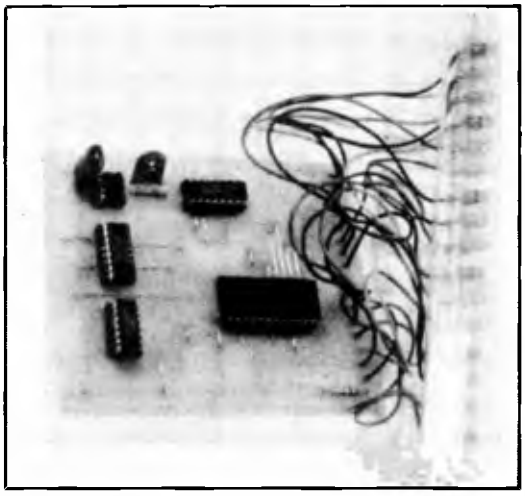

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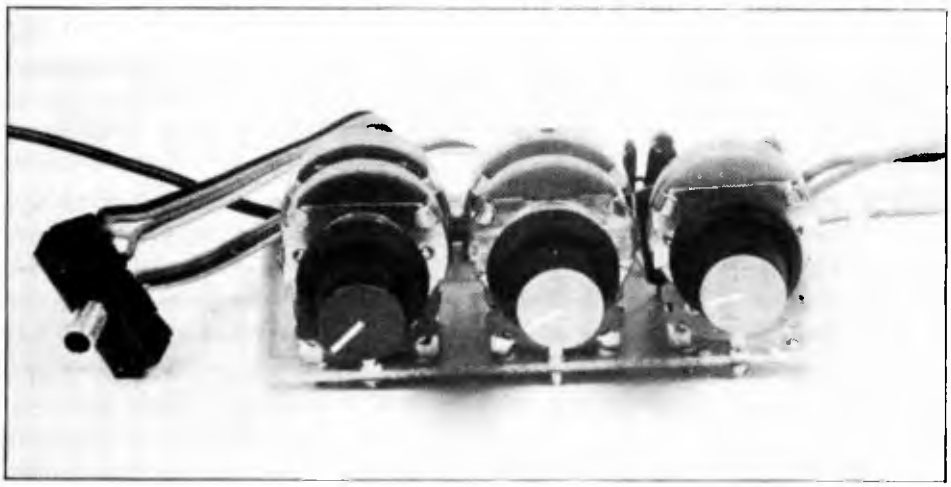
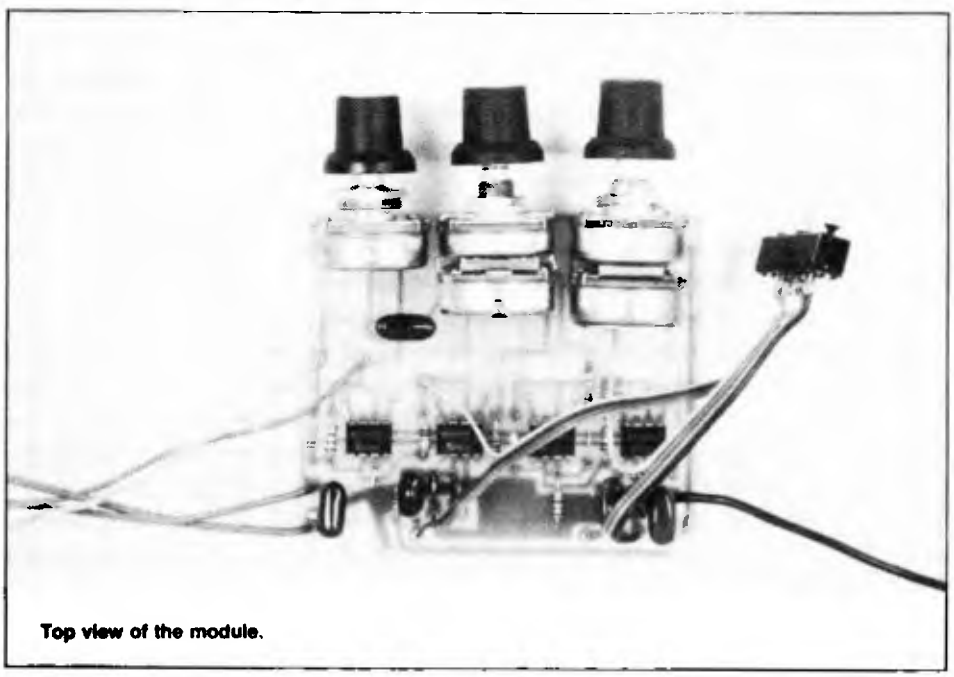
PARAMETRIC EQUALISER

Does your music system want a new frequency response? Does your guitar or keyboard need some equalisation to brighten the sound? Well, here is a module which can be used by itself on individual instruments or ganged to equalise your music system.

Neale Hancock





Top view of the module.

GRAPHIC EQUALISERS are widely used and accepted by audio enthusiasts as a means of correcting the acoustic deficiencies of a listening space. They are also used (probably by the majority of us) to make a stereo system sound better, by making the bass thump and adding more sparkle to the treble. The graphic equaliser is one way of optimising the frequency response of a music system to give our ears what they want.

Equalisation is not a process solely used in hi-fi applications. It's also used in public address systems as a way of eliminating feedback and in recording studios as a way to give an instrument a desired sound. In recording situations the parametric equaliser is a very versatile instrument, because it can be cascaded to give overall equalisation of a recording or used individually on separate instruments.

Both graphic and parametric equalisers use active bandpass filters to achieve equalisation. But whereas graphic equalisers use a number of preset bandpass filters called 'gyrators' (one for each slider on the front panel), parametric equalisers are tunable bandpass filters. This use of tunable bandpass filters in parametric equalisers allows each band to be more effective, thus reducing the number of bands required. And the increased efficiency allows a multiband parametric equaliser to be modular in design, with one bandpass filter in each module, making it more versatile than the graphic equaliser in the studio.

However, the ETI-1406 parametric equaliser module is designed to be used in any application where equalisation is required. These modules can be used independently or connected in series to form a multiband equaliser. The unit requires a signal of 100 mVrms line level or greater (up to 700 mV) to drive it, and runs from a ±15 volt supply. Casing details are left up to the user.

FREQUENCY RESPONSES (see text).

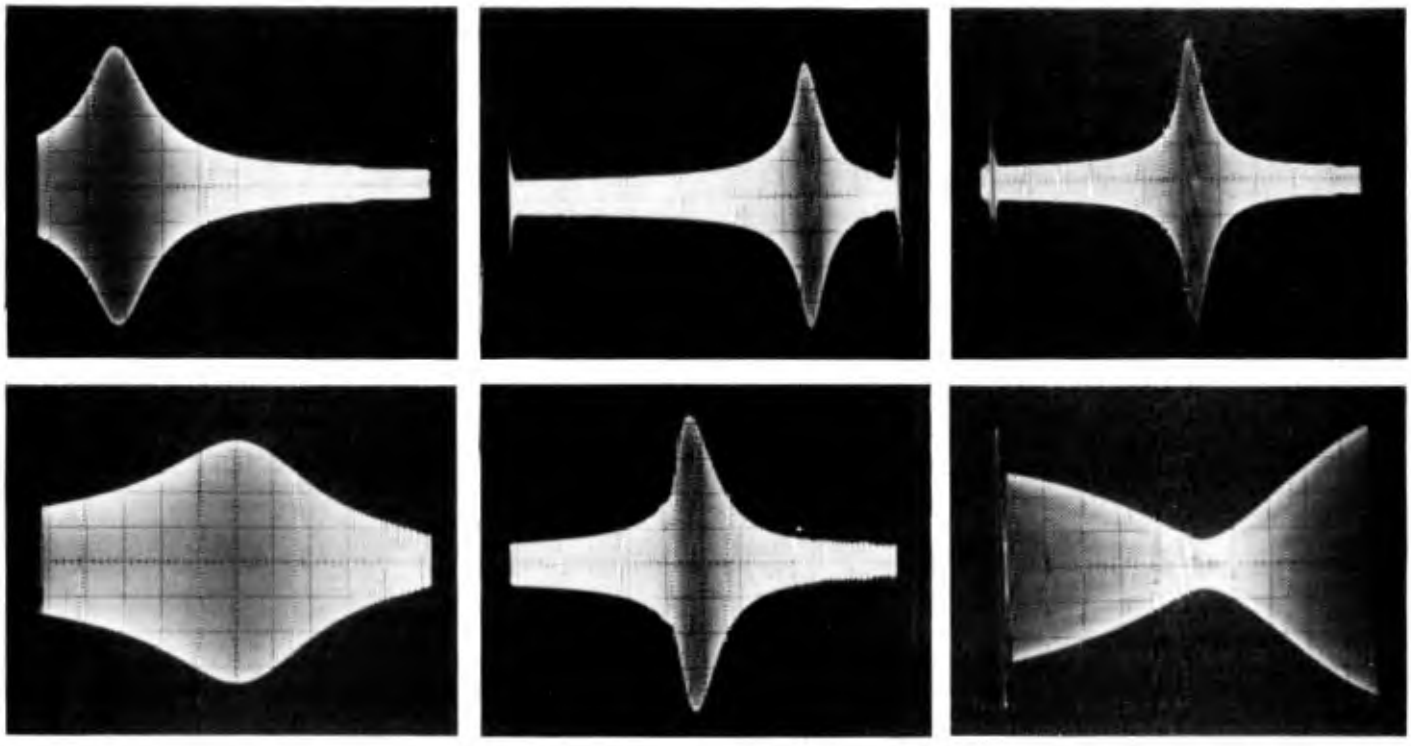
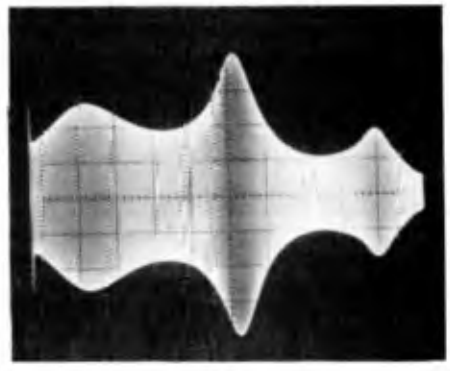


TABLE 1. PERFORMANCE OF ETI-1406

Range of centre frequencies	20 Hz to 19 kHz	Continuously adjustable
Range of Q	1 to 10	
Cut	−23 dB	
Boost	+18 dB	
Roll off	15 dB/octave	
Dynamic range	100 dB	measured at maximum gain and maximum Q
S/N ratio	90 dB	
Distortion	0.005%	

Measured at 1 kHz and a signal level of 500 Vrms.



Circuit concepts

As I mentioned earlier, the parametric equaliser modules consist of tunable active bandpass filters. To make a bandpass filter tunable, parameters such as centre frequency, bandwidth and the amount of cut and boost are made adjustable. Graphic equalisers have the centre frequency and width of the band preset, with only the cut and boost variable.

The accompanying series of photographs shows the effect on the frequency response of changing the tunable parameters. All the photographs show the same range of frequencies being swept, with the lower frequency on the left (2.6 kHz) and the higher frequency on the right (7.5 kHz).

Figures 1 and 2 show the effect of shifting the centre frequency of the parametric equaliser. Figure 1 shows the parametric equaliser set on a high frequency which would result in a boost of the frequencies around the peak. Figure 2 shows it set to a lower frequency.

Figures 3 and 4 illustrate the effect of increasing or decreasing the width of the passband. This is also referred to as the Q. In Figure 3 the circuit has a high Q, thus a narrow range of frequencies around the peak is emphasised. Figure 4 has a low Q and shows a broad range of frequencies being emphasised.

Figures 5 and 6 show boost and cut of the range of frequencies. In Figure 6 the signal was amplified vertically so that the cut could be more closely observed.

The circuit for the parametric equaliser is based on a state variable filter circuit. This type of filter features low pass, high pass and bandpass outputs. They are also capable of providing a high Q and they can be readily tuned.

To convert a state variable filter into a parametric equaliser, the circuit has to be modified to so that its Q, centre frequency and gain are all variable. Q can be varied by replacing the pair of resistors used to set it with a dual-ganging potentiometer. The centre frequency can be tuned by using a switch to select the range and a dual-ganging potentiometer to tune the centre frequency of the filter within that range. The range is selected by switching in different capacitor values and the dual-ganging potentiometer replaces the resistor pair used to set the centre frequency.

To enable the filter to have variable gain or attenuation (boost or cut) at the centre frequency, a gain stage is added to the state variable filter circuit. This gain stage allows the filter to have bandpass or band reject characteristics.

The circuit has been designed using high performance op-amps, such as the NE-5534AN and the TL-071. Of these two op-amps the NE-5534AN gives the best results for noise and distortion, but at a higher component cost. The specifications for the ▶

circuit using NE-5534AN op-amps are listed in Table 1. The circuit can also use the good old 741 op-amp however higher levels of noise and distortion can be expected when using this device.

Construction

Commence construction by examining the pc board for broken tracks, and bridges between tracks. The first components to be mounted are the resistors, capacitors and the link. Next mount the ICs, but first check their orientation with the overlay. To supply the voltage rails of the modules, the +15 and −15 volt power supply is used. The ETI-581 dual power supply would be ideal in this case.

To keep the number of flying leads in the project to a minimum I have used pcb-mounting pots. The only hassle involved in using these pots is that you may need to drill 2 mm mounting holes in the pc board to accommodate their pins. After the mounting holes have been drilled the pots can be mounted on the board.

The triple-throw toggle switch can now be connected to the pc board. The best way of connecting the switch is to use ribbon cable as it makes the wiring neater and simpler. Try to obtain the thicker gauge cable as it is easier to work with in this case.

The wires connecting the input and output sockets and the power supply to the pc board can now be connected. It is best to leave these connections until you have decided what case to use.

The type of case used to house the parametric equaliser depends largely on how you want to use it. For instance, if you use a single module as an independent unit, it should be housed in a case by itself. However, if you are constructing a multiband parametric equaliser or integrating the modules into a music system, you will have to drill out your case to suit.

The component overlay shows the purpose of each pot, and what frequency range is selected by each position on the triple-throw switch. The overlay also shows how to connect the modules in series, using switched 3.5 mm or 6.5 mm phono jacks, to create a flexible multiband parametric equaliser. The use of switched jacks between each module allows them to be used independently.

Using it

When using individual parametric equaliser modules to modify the sound of a musical instrument, first set the Q control to the centre position, the frequency range selection switch to its centre position and the cut/boost control either fully clockwise or fully anticlockwise.

Play a sustained note (preferably middle C) and turn the centre frequency control until you hear the sound of the note change. If the cut/boost control is turned fully anti-

HOW IT WORKS — ETI-1406

As mentioned in the text, the circuit is based around an active state variable filter. The op-amps in this filter are ICs 1, 2 and 3. The output from IC1 is high pass, the output from IC3 is low pass and the output from IC2 is bandpass. The output from IC2 goes into the gain stage, which consists of IC4, R6, R9 and RV3.

The centre frequency of the parametric equaliser is determined by resistors RV2, R5 and R10 and capacitors C2 and C7. The frequency range is selected by switching in a pair of capacitors using a dual-pole triple-throw switch, SW1. The frequencies within the range are determined by the resistor pair R5 and R10 with the dual-ganging potentiometer RV2. The equation which sets the centre frequency, fc, is:

$$fc = 1/2\,(RV2 + R5)Cx$$

where Cx can be C2, C3 or C4.

This equation could also be written using R10, C5, C6 and C7 since all these components are the matching pairs of those in the equation.

C2 and C5 select the frequency range of 2 kHz to 20 kHz, C3 and C6 select the range 200 Hz to 2 kHz and the pair C4 and C7 selects the range 20 Hz to 200 Hz. The frequencies within the ranges are obtained by using a dual-ganging potentiometer RV2.

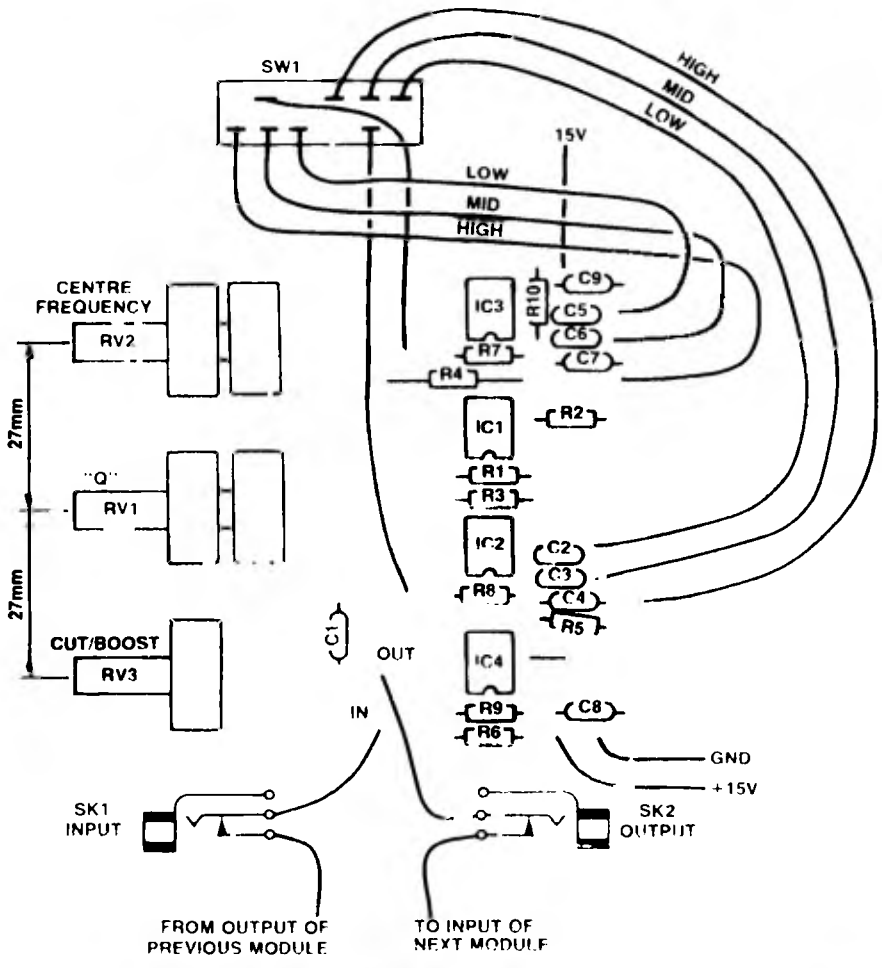
The highest frequency in the range is obtained when RV2 is turned fully clockwise making RV2 equal to zero in the equation above. Therefore, R5 and R10 set the high end of the frequency range. When RV2 is turned fully anti-clockwise its value is equal to 100k in the equation above, thus setting the low end of the frequency range.

The Q of the parametric equaliser is set by the combination of R2, R4 and RV1. The equation used to determine the Q of a state variable filter is as follows:

$$\begin{aligned}(R4 + RV1)/R2 &= 3Q - 1\\ 1 + (R4 + RV1)/R2 &= 3Q\\ (1 + (R4 + RV1)/R2)/3 &= Q\end{aligned}$$

By substituting in the values of R2 and R4 as well as the maximum and minimum values for RV1, a maximum value for Q is 10 and a minimum value for Q is 1.

The gain stage gives the parametric equaliser circuit the ability to cut or boost the frequencies to which the filter is tuned. RV3 gives control over the amount of cut or boost while R6 and R9 set the overall gain of this stage. The capacitors C8 and C9 are there to remove high frequency noise from the supply rails.



PARTS LIST — ETI-1406

Resistors.....all ¼W, 5%
R1, 7.....100k
R2.....3k9
R3-6, 8, 10.....10k
R9.....22k
RV1, 2.....100k dual-ganging linear with pc mounting pins
RV3.....10k linear with pcb mounting pins

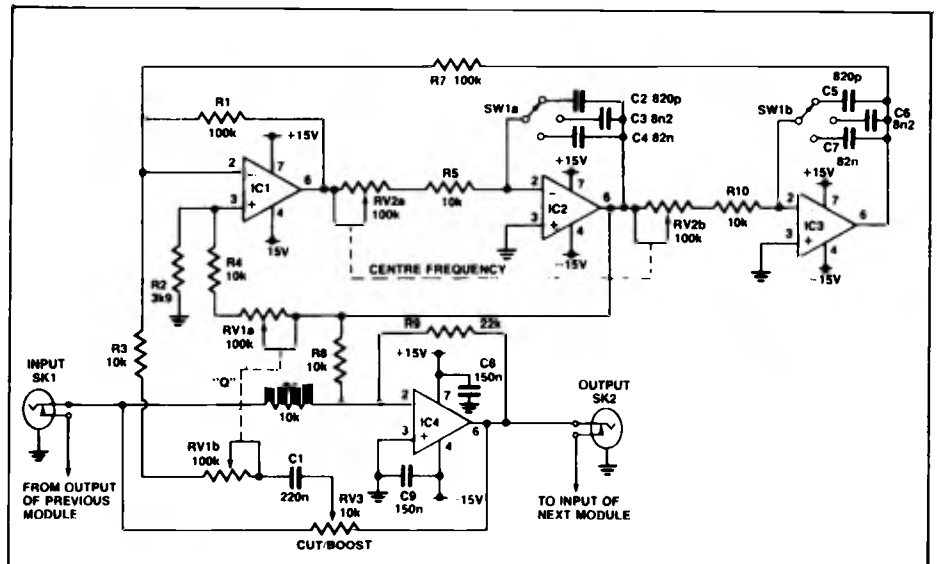
Capacitors
C1.....220n greencap
C2, 5.....820p ceramic
C3, 6.....8n2 greencap
C4, 7.....82n greencap

Semiconductors
IC1-4.....NE-5534AN or TL-071 (see text)

Miscellaneous
ETI-1406 pc board; 3 x potentiometer knobs; 2 x switched phono sockets; dual-pole triple-throw switch; hookup wire; case to suit.

Price estimate: $22-$33*

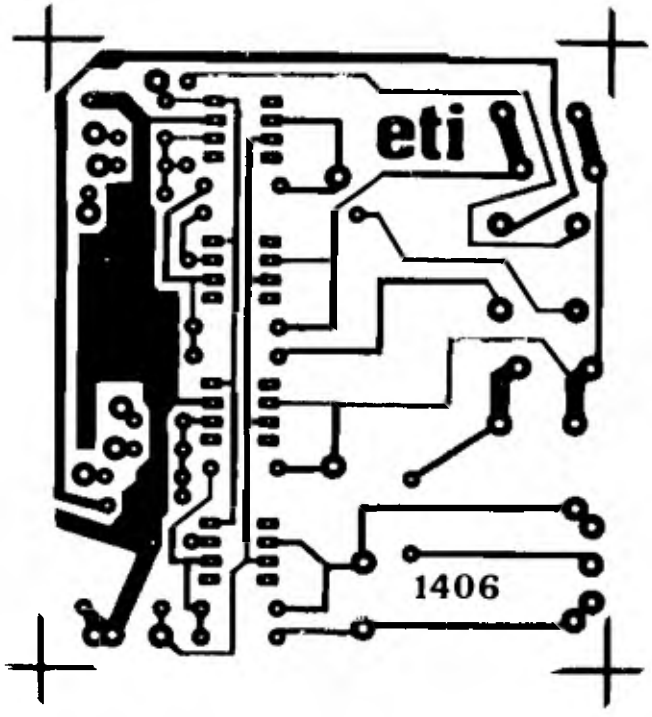
*The lower figure corresponds to the circuit using TL-071s



clockwise, the effect will be a dulling of the note, alternatively the sound will be brighter if the cut/boost control is turned fully clockwise. By turning the Q control clockwise the range of notes dulled or brightened will be reduced. When it is turned anticlockwise the range of notes will be increased.

A good multiband parametric equaliser can be created by using three or four modules in series. Using such a multiband equaliser on orchestrated music would require a similar procedure to that outlined above. The only differences are that the input into the equaliser is different and that there are more bands to tune.

When using a number of modules in series each one increases the gain and the Q of the system. Make sure that the first module in the system does not have a high gain or Q; this applies to a lesser extent to each successive module. If the gain or the Q of the system is too large the result will be excessive distortion of the musical signal. ●



Ian J Truscott's

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Project 169

LOW DISTORTION AUDIO OSCILLATOR

Part 1

Our gnomes in the market research field have told us that ETI readers are more interested in hi-fi than the average. No great revelation, you probably built your own system? Well this project puts that to the test. It's an audio oscillator that allows you to accurately measure audio performance so you can be more authoritative than the average.

Ian Thomas

JUST ABOUT EVERYBODY in this civilised country of ours has a hi-fi system of some sort or another. Since you're reading this magazine you almost certainly take a more than passing interest in how well it works and have probably built some, maybe all of it yourself. If, like most of us, you aren't blessed with infinite financial resources then you probably put it together and said "well it seems to sound OK" and left the testing of your masterpiece at that. You probably knew that this wasn't the most definitive of tests but put the acquiring of good audio test equipment in the "too hard (expensive)" basket. At the request of our editor I've finally gotten around to doing something to rectify this situation.

The very first and most important piece of test equipment you'll need is an audio oscillator to provide a signal source whose performance is at least an order of magnitude better than the equipment you want to test. Audio oscillators have been around for an awful long time now and people have built very large and successful businesses around them. I've been assured that it really is true that two gentlemen by the names of Bill Hewlett and Dave Packard started building simple one valve Wien bridge audio oscillators in their garage in 1939. Their company is now worth billions of dollars so there has to be a future in it! Perhaps you could duplicate their efforts (if you do please remember where you got the idea!).

In modern hi-fi equipment the most commonly measured and quoted gauge of performance is referred to as the total harmonic distortion of the equipment and is usually given as a percentage although in the professional literature it is often given in dB. When a signal is passed through equipment such as an amplifier the signal that emerges from the equipment is not an exact replica of the signal that went in. The amplifier tends to change the waveform slightly in the process of amplifying it.

In order to test the equipment it is necessary to apply a signal to the input that is exactly known so that some form of test can be applied to the output to see if it has been corrupted. Normal voice or music signals are very complex and it is impossible to apply any form of quantitative test to them apart from "well it sort of sounds OK". By far the simplest form of signal to handle both mathematically and in test equipment is a sine wave which can be described as

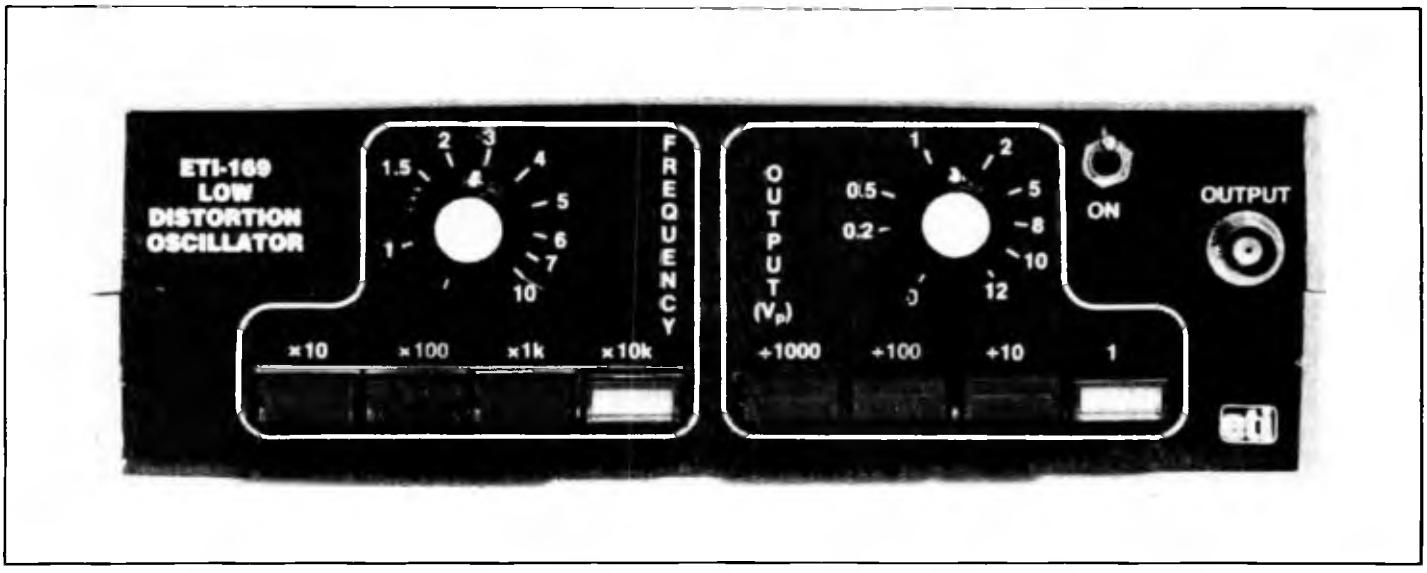
$$V = V_0 \sin(2\pi ft)$$

where f is the frequency of the sine wave. If this signal is applied to the input of an imperfect amplifier (as they all are) what emerges will be the input sine wave multiplied by the gain of the amplifier *plus* other signals as well. These other signals which are generated in the amplifier will have frequencies of 2f, 3f, 4f and so on. These are called harmonics of the input signal and are caused by distortion in the amplifier itself.

A bloke by the name of Fourier way back when put all this on a mathematical footing which I won't bore you with (assuming I could remember it) but the short of it is that if you have a regular periodic waveform which isn't a sine wave then it can be made up by the sum of a lot of sine waves with frequencies that are harmonically related. As the signal that emerges from an amplifier when a perfect sine wave is put in is no longer a perfect sine wave, the output can be dissected into the amplified perfect sine wave and the resultant Fourier components which are harmonics of the input signal. Because they are harmonics of the sine wave input the distortion is called harmonic distortion; if all the harmonics are lumped together and measured the result is a total of all the harmonics — hence total harmonic distortion! Now you know what it really means when you see 'thd' on the data sheet.

For more consumer equipment the harmonic distortion is always given as a total but in many applications the level of each individual harmonic is given separately or odd and even harmonics may be separated out. This can help a lot in identifying the mechanisms that are causing the distortion.

The nub of all this is that the signal to be applied to the amplifier must not contain any harmonics of its own or the harmonics from the oscillator can't be separated from those generated in the amplifier and spuriously high (or even low!) readings are obtained. Hence the need for a low distortion oscillator. Most cheapie sine wave oscillators are absolutely useless for testing audio equipment as their disortion is usually around 1% or −40 dB. That is, the total of all the harmonics is one hundredth of a fundamental sine wave. Even the grottiest amplifier can beat this hands down; in fact you'd have to work at it to build one this bad.



Amplifier distortions normally run from 0.1% or −60 dB (crummy) to 0.001% or −100 dB (so good it's very hard to measure and doesn't really matter!). This latter figure sets the required performance of an oscillator if it's to be used in thd testing. That is, the sum of all the harmonics that come out of the oscillator should be about −100 dB or 0.001% of the fundamental. This is a pretty tall order but it seems a good place to start.

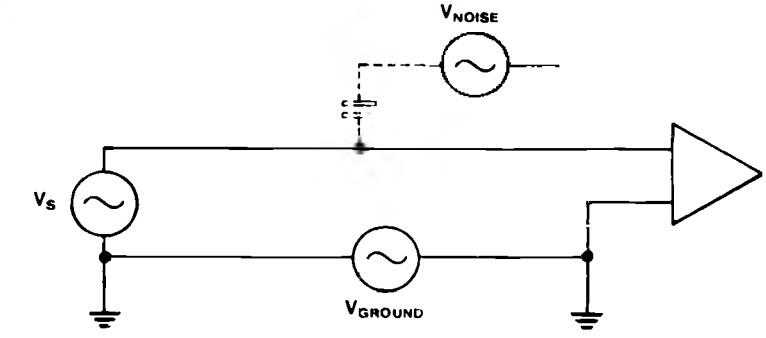
There are other factors that must be considered as well as the oscillator. So far I've only discussed the harmonics of the fundamental signal. As well as these any electronic circuit will generate electrical noise. This is a signal that is characterised by having components at all frequencies and sounds like the hiss you get from a tape recorder with a blank tape. Fields will also be picked up from mains operated equipment such as transformers and add in components usually at 50 Hz and 150 Hz. As the usual method to measure thd is to use a very narrow selective filter to remove the fundamental and then measure what's left, all these unwanted signals will degrade the measurement of distortion figures.

The range of frequencies to be covered by a useful oscillator is usually set by how much you want to pay for it. The lowest frequency is set by the control circuitry to stabilise the oscillator (more of this later) and for most purposes is set at 10 Hz (you can't hear this low anyway!). The upper frequency is set by the choice of operational amplifiers to be used. To keep costs under control I decided to base all designs around the old trusty NE5534 which sets an upper limit around 100 kHz. The last thing to be decided is the type of output the oscillator should have. The output level is also set by the choice of operational amplifier and limits output swing to ±12 volts peak.

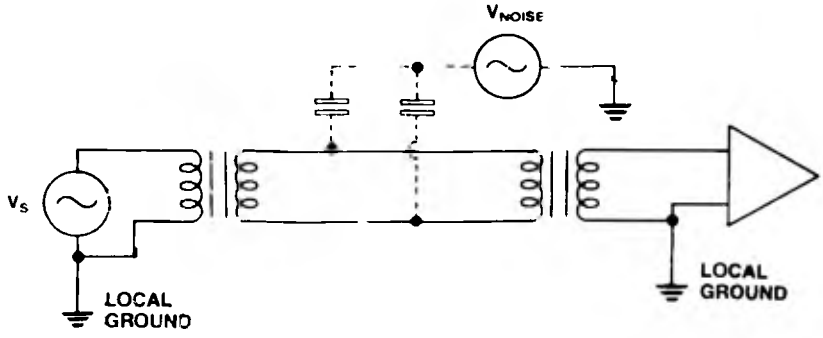
If an op-amp output is brought directly to the output terminals, this enables people to do very bad things to the output circuitry so it's nicer to have some sort of series resistor in the output. In the industry this is normally chosen as 600 ohms (for a lot of reasons) and ensures that no matter how the output is mistreated (within reason) the oscillator can carry on. Another good reason to set the output impedance at 600 ohms is that then attenuators can be placed after the final amplifier. These will attenuate both the signal and any noise and distortion equally and thus will maintain the distortion performance of the oscillator at very low levels. This means that if you want to measure the performance of, say, a preamplifier then you can be sure the signal is still clean. To generate these low level signals I decided to include attenuators of 20, 40 and 60 dB or 10x, 100x and 1000x and allowed for a continuous adjustment between.

The last major decision to be made about the output was to decide whether it should be balanced or unbalanced. In a lot of the ▶

BALANCING OUTPUTS



UNBALANCED
In an unbalanced condition the signal seen at the input of the receiving amplifier is degraded by the addition of any ground loop voltages plus any stray signals that are capacitively coupled into the line.



BALANCED
With balance, ground loop voltages have no effect on the input as the input transformer 'floats' the wanted signal on top of any ground signals and the amplifier is able to ignore them. Capacitively coupled signals tend to be equally coupled into both lines of the balanced pair to be removed by the transformer.

older oscillators it was very common to have a transformer in the output. This created what is known as a balanced output which has many advantages. The most important one relates to earthing in an audio system (see box) and makes an awful lot of problems simply go away! For this reason alone all broadcasting and many recording studios use *all* balanced circuits. The big disadvantage is cost. Using today's design techniques means transformers aren't necessary any more but it still doubles the complexity of the output so I decided to settle for an unbalanced output.

Which oscillator circuit?

Oscillator circuits are as many and varied as brands of soap powder and all have their plusses and minuses. The first type that can be ruled out is any form of inductor based oscillator. To build an LC oscillator that worked at 10 Hz you'd need an inductor the size of a brick that'd work just great as an antenna to pick up mains hum. Clearly some form of resistor capacitor oscillator must be used. Probably the most common oscillator configuration used is the Wien bridge (see Figure 1). This design goes way back to before Hewlett-Packard made good use of it and is still used in designs today.

The Wien bridge serves to illustrate what is required for an oscillator to work. Referring to Figure 1 you'll see that the oscillator consists of an op-amp (actually any amplifier will do) with negative feedback around it to control the gain. The elements that form the frequency selective part of the oscillator are the two capacitors and the two variable resistors. If the attenuation from the output to the positive input is calculated then it can be shown that at a frequency equal to $1/2\pi RC$ the two resistors and capacitors divide the voltage at the output by exactly 3 and the voltage at the positive input is exactly in phase with the output voltage. At higher or lower frequencies the attenuation is greater and the two voltages are no longer in phase.

Suppose now that R_x and R_y are adjusted so the attenuation through them is also exactly 3. As they are only resistors the voltage on the negative input will also be exactly in phase with the output and under these conditions the whole network has infinite gain *but only at one frequency*. For frequencies greater or less than $1/2\pi RC$ the positive feedback drops away and the overall network gain becomes finite again.

If an amplifier configuration has infinite gain, it will oscillate as it takes no input signal to produce an output which is exactly what is wanted and what happens. If the attenuation through R_x and R_y is adjusted to be slightly less than 1/3 then the oscillation will stop; if it is slightly greater than 1/3 then the amplifier output will be driven hard up against the rails so the average gain over the entire swing is correct for oscillation. The gain has to be adjusted to be exactly correct for oscillation without clipping.

In Figure 1 the frequency adjusting resistors are conveniently shown as R where two resistors are being changed at the same time to set the frequency. It is assumed that the two resistors are always exactly equal. In the real world this is very hard to do but if you dig into the mathematics a bit you'll find that oscillation can still occur if they aren't equal. All that's necessary is to change the attenuation of the R_x/R_y leg of the bridge. Similarly if the two capacitors aren't equal then once again adjusting R_x and R_y will do the deed.

This is where practicalities start to intrude. If the two variable resistors don't track exactly then when you change frequency R_x or R_y must be adjusted automatically to set up the right conditions for oscillation again. As the amount of adjustment is (more or less) proportional to the mismatch in the variable resistors, a badly tracking dual gang pot will require considerable adjustment of R_y by electronic means and *all electronically variable resistors cause distortion!* (R_y is normally chosen as one end is connected to ground.) This is just one of the rules of the game. In order to build a very low distortion oscillator the two variable pots must track to within a per cent or so. You can buy them but you won't get much change out of $100. This just isn't a proposition for a cheap oscillator.

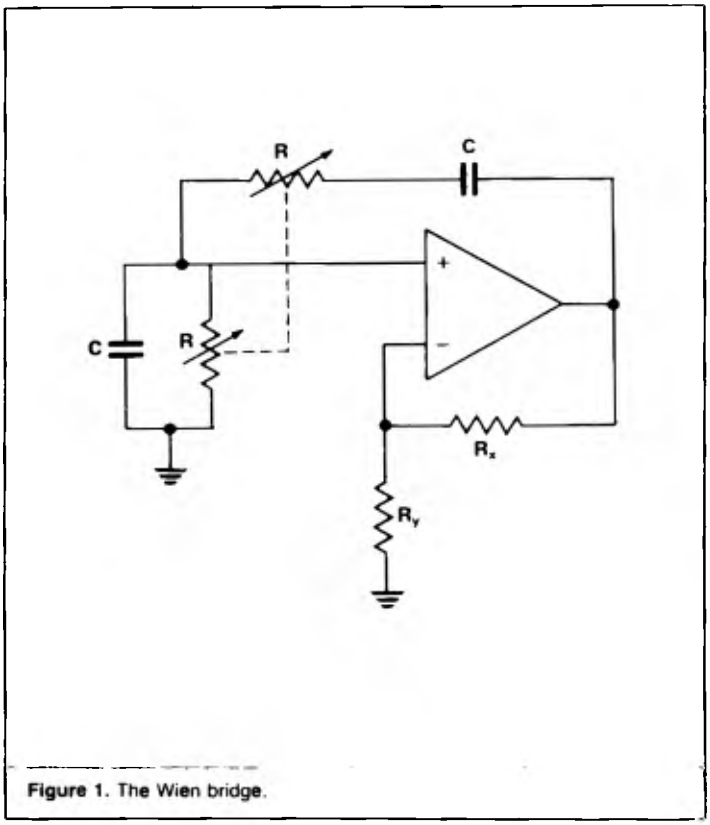


Figure 1. The Wien bridge.

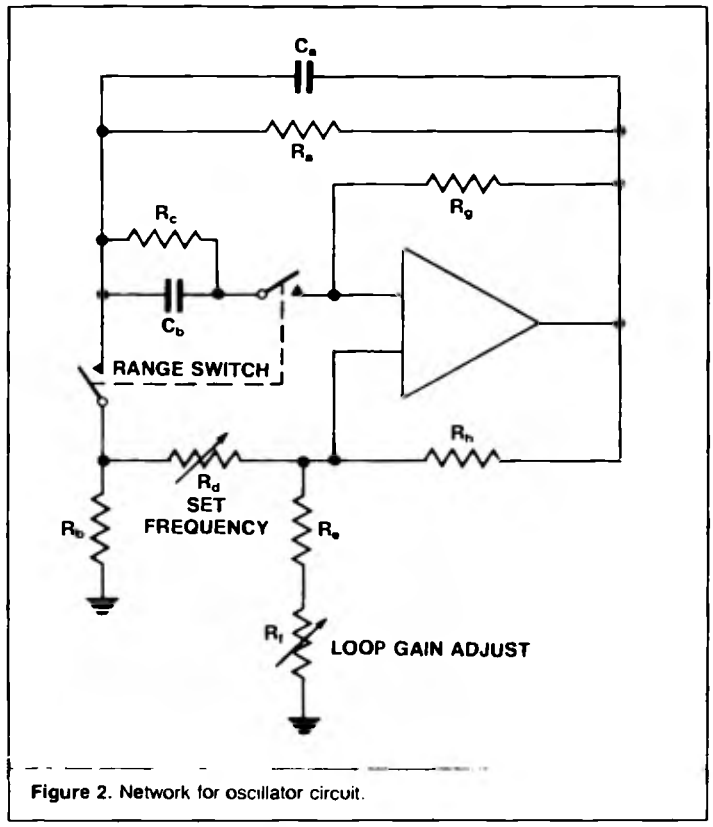
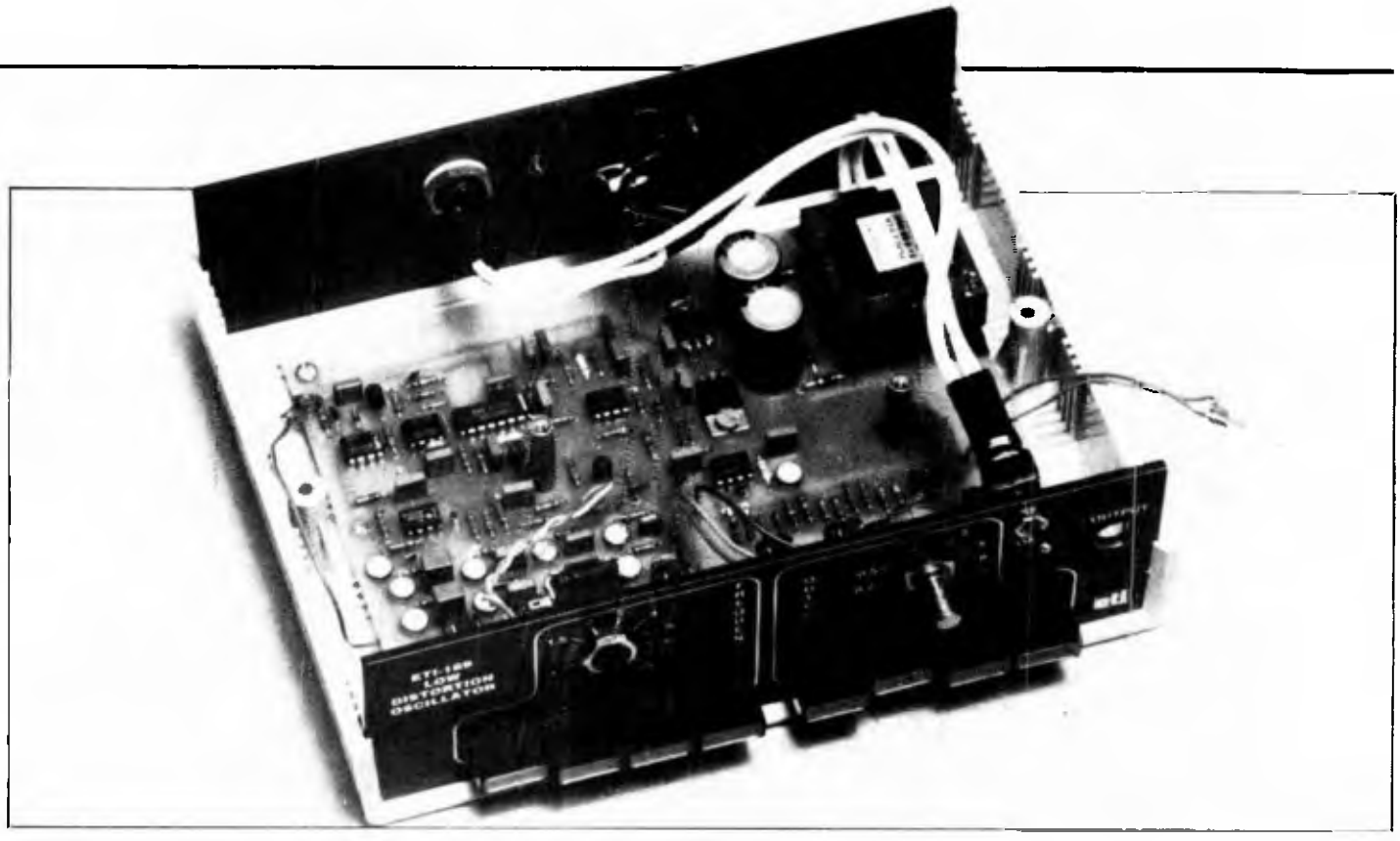


Figure 2. Network for oscillator circuit.



The capacitors also cause a similar problem as it is normal to only use the variable resistors to give a frequency range of 10 to 1 and then switch capacitors to switch ranges. In theory the same capacitors could be used for the entire range but in practice the impedances that would have to be driven at 10 Hz and 100 Hz become silly. Thus in the Wien bridge capacitors with tolerances of 1% are needed. Once again you can get them if you've got the dollars but I wanted this oscillator to be cheap (but, of course, superb!).

A little research into oscillator configurations showed that there has been a fair bit of work done on single control element oscillators. Much of it seems to have been done by Indian gentlemen with much brains but a research budget that wouldn't keep a mouse in cheese. This tends to restrict efforts to tinkering with exotic circuits on paper.

The type of circuit I was after was one where trimpots could be included to adjust out the tolerance variations in all the capacitors and, if possible, a ninth trimmer to adjust for the absolute value of the single gang frequency setting potentiometer (there are eight capacitors for the four frequency ranges). I couldn't find any configuration that was ideal but an article by V. Prem Pyara, S.C. Dutta Roy and S.S. Jamuar gave a method of finding a class of single control element oscillators so I could stir things around for myself.

The network I finally settled on is shown in Figure 2. Obviously it isn't anything like a Wien bridge but all the basic rules still apply. There is a condition that must be preserved in order that the circuit oscillate and if this condition is maintained then a simple resistance-frequency law can be established. Cranking through pages of mathematics I was able to derive the simple law for the condition for oscillation if $R_b = R_f$:

$$-\frac{C_a}{C_b} = \frac{\frac{1}{R_b} - \left(\frac{1}{R_g} + \frac{1}{R_a}\right)}{\frac{1}{R_g} + \frac{1}{R_c}}$$

This may seem all a bit overwhelming but it tells one very important thing. R_d, the frequency control pot, *does not appear in the condition for oscillation* (bewdy!).

More thrashing about with algebra showed that if R_a, R_c and R_g were made adjustable then not only could the oscillation condition above be set up but the frequency of oscillation could be made equal to:

$$(2\pi f)^2 = \frac{2}{R_d R_g C_a C_b}$$

Thus by adjusting R_g it is possible to adjust out any tolerancing errors in the frequency set pot, R_f. Then by adjusting R_a and R_c tolerances in C_a and C_b can be adjusted out.

A quick rats' nest verified that all the mathematics told no lies and quite dramatic control of frequency could be obtained without affecting the oscillation amplitude. According to the numbers the frequency could be taken to infinity if R_d was made equal to 0, and this was very nearly what happened. The only limit was the bandwidth of the operational amplifier and the only problem that remained was the fact that the frequency is proportional to the square root of $1/R_d$. This makes the frequency scale very open for low frequencies and squeezed up at the upper end. However a bit of searching showed that I could get an inverse log law potentiometer from Allen Bradley in Sydney that more or less cancelled the nonlinearity caused by the square root law of the oscillator and gave a frequency-pot rotation law that was usable. This seemed to sort out all the problems with the oscillator itself. The last thing to be dealt with was the control of oscillator level.

In the final oscillator circuit R_h was chosen as the resistor to be varied to set oscillator loop gain. If one had the patience of Job and reflexes that would make a cat look sluggish then one could sit there and fiddle a trimpot to hold the loop gain steady but an automatic loop gain adjust is better. And that is where distortion mechanisms start to appear! R_h need only have about a ±2% adjust but this must be done by a control voltage. About the only voltage variable resistors that can be bought easily in Australia are FETs. If a field effect transistor has zero drain-source voltage applied to it, then it acts as a resistor whose value is varied by the gate bias. However if the applied ac signal becomes too large then it starts to produce distortion as the resistance of the channel is affected by the bias. This can be minimised by applying an ac component to the gate as well and I found that for the small range of resistance control needed it worked just fine.

A far worse problem than this is the possibility of components of the oscillator output voltage getting back to the control gate. The oscillator stabilisation loop consists of an output level detector and a control loop amplifier — loop filter to generate a control ▶

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voltage for the FET. It is imperative that the output level detector produce as near as possible a dc voltage that is proportional to the ac out of the oscillator. If any ac component is left in the detector output then it will modulate the FET and cause distortion. This dc control voltage must be generated for input frequencies between 10 Hz and 100 kHz which says that any form of rectifying and filtering is out of the question as the detector is part of a control loop.

The way I chose to do it is by using a peak detector which is reset every cycle of the oscillator output (see "How It Works"). This generates a dc voltage equal to the oscillator peak output voltage for a bit more than half the period of the oscillator. When the dc output is stable it is connected to the control integrator and when it is changing the integrator input is switched off. This very nicely removes any ac component from the control output and ensures that the FET only sees dc.

Like any control loop the oscillator control loop must be stabilised and this presents its own set of problems. The loop is stabilised by an extended RC circuit in the integrator that compares the dc from the peak detector with a reference dc set up by a zener diode. This makes sure that the control loop gain and phase are right over the entire 10 Hz to 100 kHz range. All this may seem a little complicated when compared to some other techniques you may have seen (such as a light bulb in the feedback loop!) but this level control circuit is the essence of producing low distortion signals. The oscillator circuit alone, if left to itself and operated away from clipping, will produce almost no distortion (NE5534s are very good) and in practical circuits almost all the distortion is added in by the stabilisation loop. This stabilisation loop solves that problem almost completely. It is only necessary to adjust the capacitor compensation trimmers so the FET operates in the best region to get distortion performance that was so low I couldn't measure it.

The output circuit and attenuators presented little difficulty as the switch bank I chose to use (you can get it from either Jaycar or Geoff Wood Electronics) has two contact changeovers. This let me use a 'T' type switching configuration to minimise capacitive hopover. The problem is that if the −60 dB attenuator is selected then signal from the higher outputs is capacitively coupled to the output and you don't get −60 dB at 100 kHz (see Figure 3). Using a 'T' configuration shorts out all the capacitive hopover and gives the correct level. ●

Details of the construction, circuit, overlay and parts will be given in the November issue of ETI.

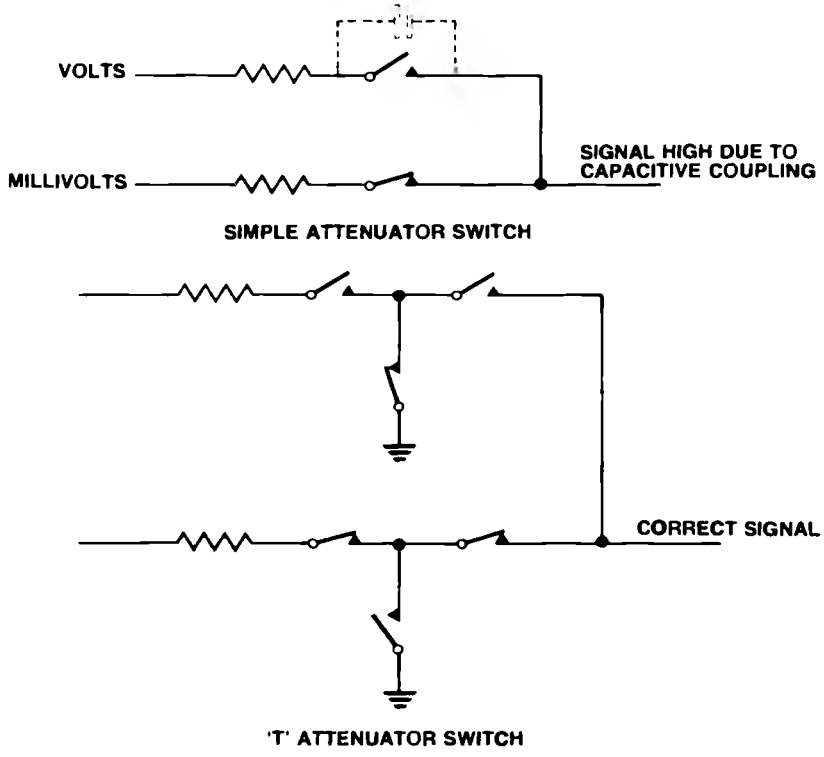


Figure 3. 'T' attenuator switch.

LOW DISTORTION AUDIO OSCILLATOR

Part 2

Last month we told you the principles and compromises in designing this impressive audio oscillator. It was such a comprehensive discussion we had to split the project into two parts. Here we resume with a guide to construction, circuit details and testing advice.

Ian Thomas

SO MUCH FOR all the reasons for the eventual circuit last month. Now for how to use it.

Construction

I chose to use a plastic instrument case available from Geoff Wood, Jaycar or Altronics. I think just about every electronics store will stock one that's OK. The plastic boxes are neater but the metal ones do make the oscillator less prone to hum pickup. You pays your money and makes your choice!

If you want to do your own layout and make the board fit a different case, the most important thing of all is to keep the RC parts of the oscillator *as far as possible from the power transformer*. Power transformers radiate 50 Hz fields and these are entirely too easy to get into the oscillator. If you look at the layout of the board, you'll see that they are on opposite diagonal corners of the board and I still had some trouble. For the same reason (hum pickup) I chose to use the miniature Bourns trimpots to minimise board area used by the selective components in the oscillator. These are also available from Geoff Wood and were, in fact, a lot cheaper than the normal cermet trimmers. On the subject of trimmers it's *absolutely essential* that good quality cermet trimpots be used as the cruddy old carbon film ones really aren't stable enough. All the trimpots are in frequency determining networks and if an older type is used, the output frequency would be all over the place like a dog's breakfast. Similar remarks apply to all the fixed resistors. Ideally they should be ±1% metal film resistors not so much for the ±1% as for the stability with time and temperature although in the prototype they were mainly ±2% and seemed to work OK.

The capacitors used in the frequency determining networks are all metallised polyester and are encapsulated in plastic cases. The types that're suitable are ERO (Roederstein) type MKT1817 or MKT1826 or Wima type PR21 or RS21 or some fair dinkum equivalent. If you do decide to go for a rock bottom budget unit and use greencaps let me know how they work (by mail — not in person!). The point about the capacitors I specified is that they have a known temperature characteristic which only gives a ±0.5% change over the normal operating temperature range.

The safest way to get the board layout is to copy the one given or buy a mask from ETI (if you put any value on your time this is really far cheaper). The board is made from single sided 1/16 inch epoxy glass board. I don't recommend using paper phenolic type boards as their leakage performance is a bit sus. If you are doing your own layout take particular care to get the spacing right for the switch banks pins (they're *@#!! not on 0.1 inch centres).

Etch and drill the board normally and start assembly with the power supply. Assemble only the power transformer, rectifier, diodes, filter electrolytics and voltage regulators. I VERY strongly recommend using printed circuit terminals to get 240 volts onto the board as I have been bitten far too many times.

NEXT COVER ALL THE TRACKS THAT CARRY MAINS VOLTAGE WITH INSULATING TAPE. If you don't you'll probably kill yourself. Also there are two solder pins that carry mains that stick out from the side of the little Ferguson transformer. Tape them up too. I missed them and my CRO earth clip brushed across them on the prototype (BANG!! palpitate!).

Next create for yourself a death machine — that is a length of 2 or 3 core flex with a mains plug on one end and the other end with bare wires. Connect the wires to the input terminals on the board then power the beast up. Check that you have plus and minus 15 volts coming out of the regulators. If all is well remove the plug from the mains, remove the bare ends from the terminals and lock the damn think away in a safe or something. Now that you know that the voltage regulators work you can carry on with the rest of the assembly with some confidence that the whole thing won't go up in flames when you turn it on.

As always make sure that all the ICs are in the right way and also the diodes. It's particularly important that the leads be neat and short around the oscillator (mains hum again). In the prototype I used two 1M and two 200k resistors to make up the 1.2M needed for the −60 dB attenuator as this gives the exact value. There are three wire jumpers that run just behind the frequency select switch which should be as short and straight as possible — resistor leads that've been cropped off do just fine. The last components that should go in are the two switch banks.

Testing and alignment

Before you try to mount the oscillator in the box it's a good idea to do a preliminary alignment and make sure all the ranges are working. Once the board is completely assembled reconnect the death machine to the power terminals and turn the unit on. When I do this to a brand new board I normally run my hands lightly over the components for 30 seconds or so to see if anything is getting too hot too fast (that's another reason to check the power supply first). Next check that the supply rails are still sitting at ±15 volts. If this is right then you're ready for the fun bit.

To set up the pots you really need a counter although a CRO will do in a pinch. The purpose of this adjustment is to remove the ±10% or so tolerances in the oscillator

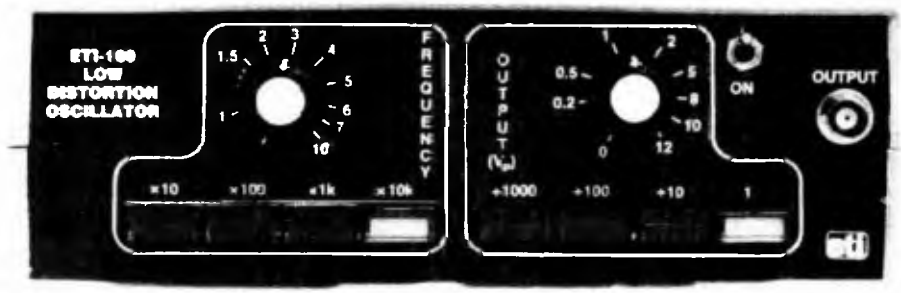
components and it can't be done properly if you can only measure frequency to ±20%. You can certainly make sure that everything is working but the frequency scale on the front panel won't be worth much.

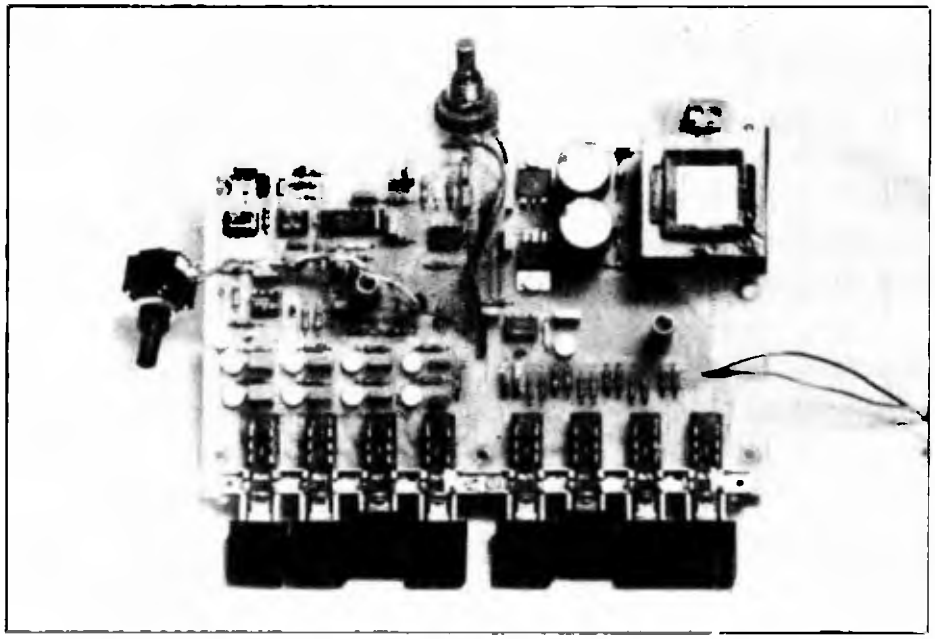
Given that you've got, begged, borrowed or whatever a counter with a 1 second timebase at least (10 seconds is better) connect it to the output and select the 100 to 1000 Hz frequency range and the 0 dB attenuation range. Connect the frequency adjustment potentiometer temporarily to its appropriate holes and tack a piece of wire across the level adjust pot holes so you get full output. Turn all nine trimpots full clockwise and turn the beast on. If all is normal the output should go up against the rails and stay there. Set RV10 (the frequency select pot) for minimum resistance or maximum frequency then start winding RV9 anticlockwise while monitoring the output. Bring it back to about mid position then start winding RV3 counterclockwise. Somewhere around mid position oscillation should start and it should be at around 1000 Hz. If this is OK, everything is looking good and you can start checking out the level control circuitry.

First check that the squarer IC2 is working. Pin 6 of IC2 should have a square wave on it which is in opposite phase to the sine wave input. The output should show no sign of oscillation during transitions. The input to the squarer on pin 2 should show the input sine wave during positive half cycles and should be diode clamped to about - 0.7 volts during negative excursions. The output from the squarer should appear on pin 10 of IC5, the CD4053. C 14 and R25 should differentiate the squarer output and a very narrow negative going pulse should appear on pin 9. Finally pin 11 of IC5 should be sitting near ground. Momentarily stop the squarer by shorting its output to ground and pin 11 should rise to about 12 volts if you're using a 10M input impedance CRO probe.

Next comes the peak detector. Check that the sine wave output from the oscillator appears on pin 3 of IC3. Next check the signal on the negative input pin 2. It should be sitting at a dc voltage equal to the peak positive swing of the oscillator with a negative step occurring every time the input signal crosses zero volts going positive. If the oscillator is not being properly level controlled due to other problems then the peak detector output may not be able to get as far positive as the oscillator input but the step should still appear every time pin 9 of IC5 is pulsed negative. If this is what you get it's time to proceed to the integrator IC4

Integrater IC4 is just a simple inverting operational amplifier with a rather messy RC network in the feedback circuit. Check that pin 3 has +6.8 volts on it and that pin 1 of IC5 has the peak detector output on it As the analogue switch in IC5 is turned off when the peak detector is reset the negative





step doesn't appear on pin 1 If the oscillator output level isn't being controlled and is swinging up against the rails then the output of the integrator IC4 pin 1 should be far negative and the output of the inverting amplifier following the integrator should be hard positive. If the level control circuitry is working (that is if the oscillator has been adjusted so it has enough control range) the integrator output will probably be sitting at a few volts positive, and the output of the inverting amplifier a few volts negative.

Last of all check that the control voltage on the gate terminal of the FET is at one half the voltage of the inverting amplifier and the control circuitry should be OK. If the oscillator output is giving bursts of oscillation there is probably a short in the RC network around the integrator. As a final check on the level control try adjusting RV3 again until the level control circuit can take over. You should see a beautiful clean sine wave with a 6.8 volt peak swing on the oscillator output. Pretty — isn't it?

Now back to setting up the oscillator frequency. When the level control is working it's a lot easier to adjust the oscillator as monitoring the control voltage out of pin 7 of IC4 tells how the adjustment is going. Connect a voltmeter there and adjust RV9 until it reads about 4 volts The next step is to adjust R7 until the oscillator output frequency is 1100 Hz and the control voltage is at 3 volts. To do this, it will be necessary to adjust both RV3 and RV4 to keep the control voltage where it's wanted. You will find that rotating RV3 clockwise lowers the control voltage, and rotating RV4 clockwise raises it. Leave RV3 in the mid position and start adjusting R4 clockwise to raise the control voltage, adjusting RV9 counterclockwise to raise the output frequency until it reads 1100 Hz. Repeat until the correct frequency is obtained with a control voltage of - 3 volts.

Next set the frequency pot to lowest (highest resistance). Leave RV9 alone and adjust both RV3 and RV4 until the output frequency is 90 Hz and the control voltage is steady at −2 volts. You will find that rotating RV3 counterclockwise lowers the frequency and raises the control voltage. Rotating RV4 counterclockwise raises both the voltage and frequency. It's easy to adjust one against the other to get the required result. Return now to the maximum frequency setting on RV10 and check that it is still 1100 Hz. If necessary readjust RV9 to the correct 1100 Hz. Return to the lowest frequency setting and reset RV3 and RV4 for 90 Hz. Repeat until it's perfect, but it should only take two or three tries. That's the first range setup completed and you can move on to the 900-11,000 Hz range. ▶

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Project 169

For starters adjust both RV5 and RV6 to mid position and select the lowest frequency setting on RV10. Adjust RV5 and RV6 until the oscillator starts; then adjust exactly as before except that you want 900 Hz. When this is right adjust RV10 to maximum frequency and check that it reads 11,000 Hz. It may not be exact and if the difference is too big for you to live with try adjusting RV9 for correct 11,000 Hz then repeating the realignment on the 100-1000 Hz range.

Exactly the same alignment process must then be done on the 9-110 Hz range. The control voltage will take a little longer to get there. The highest frequency range is a little different in that the control voltage should be adjusted for −1 volt at 9000 Hz and will go down to about −4 to −5 volts at 110,000 Hz. Once you've slogged through this lot you should have a pretty good idea of what you've built.

Finally check that the attenuators are working correctly (each step down should give an output voltage one tenth the step before) and the board is ready to go in the box. Assuming you've used the same box as I did, proceed as follows.

First locate the board in the box and note the plastic mounting pillars that will actually support the board. Next attack the box bottom with a large pair of side cutters and remove the pillars that aren't wanted. There must be about 15 pillars there and only seven are needed. Next carefully mark off exactly where the holes are needed to allow the switch banks to come through the front panel and cut the holes. As this is the front panel it pays to take a little care: if you make a mess of it your mistake will be staring at you for years!

Mark off where you want the frequency and level pots to come through and drill the holes. The same applies to the power switch and output terminals. Assemble all the components on to the front panel then slide it into the box bottom. Solder lengths of wire into the board suitable for connecting the level and frequency pots. At this stage in the assembly of the prototype, a major problem reared its ugly head.

When the board was powered up in the box with all the mains wiring in place, I found that a *large* amount of mains hum was ▶

PARTS LIST — ETI-169

Resistors ..... all 0.4 W, 2% unless noted
- R1 to 9 ..... 5k1
- R10, 13 ..... 750R
- R11 ..... 6k2
- R12 ..... 5k6
- R14 ..... 1k5
- R15, 21, 53 ..... 1k0
- R16, 17, 26, 28 ..... 1M0
- R18 ..... 220R
- R19, 20 ..... 100k
- R22, 23 ..... 33R
- R24 ..... 5R1
- R25 ..... 10k
- R27 ..... 2M2
- R29 ..... 220k
- R30 ..... 330k
- R31 ..... 470k
- R32, 33 ..... 4k7
- R34 ..... 100R
- R35 ..... 3k3
- R36, 37, 48, 49 ..... 1k2
- R38, 39 ..... 12k
- R40 ..... 680R
- R41 ..... 33k
- R42, 43 ..... 120k
- R44 ..... 620R
- R45 ..... 27k
- R46 ..... 1M0
- R47 ..... 1M5
- R50, 51, 52 ..... 10R
- RV2, 4, 5 8, 9, 13 .. 2k0 trimpot cermet*
- RV1, 3, 5, 7 ..... 5k0 trimpot cermet*
- RV10 ..... 100k pot freq set Allen Bradley 72J1N056S104B
- R11 ..... 100k trimpot cermet*
- RV12 ..... 2k linear law pot level set

* *Bourns type*

Capacitors
- C1, 2 ..... 1µ ±10% 50 V met poly*
- C3, 4, 13, 15 ..... 100n ±10% 63 V met poly*
- C5, 6, 17, 31 ..... 10n ±10% 63 V met poly*
- C7, 8 ..... 1n ±10% 63 V met poly*
- C9, 24 ..... 10p ±5% ceramic plate
- C10 ..... 47p ±5% ceramic plate
- C11 ..... 22p ±5% ceramic plate
- C12, 18 ..... 47n ±10% 63 V met poly*
- C14 ..... 220p ±5% ceramic plate
- C16 ..... 2n2 ±10% 63 V met poly*
- C19 ..... 220n ±10% 63 V met poly*
- C20, 21 ..... 470µ 25 V RB electro
- C22, 23, 24, 25, 27, 28, 30 ..... 100n ceramic monolythic
- C26 ..... 33p ±5% ceramic plate

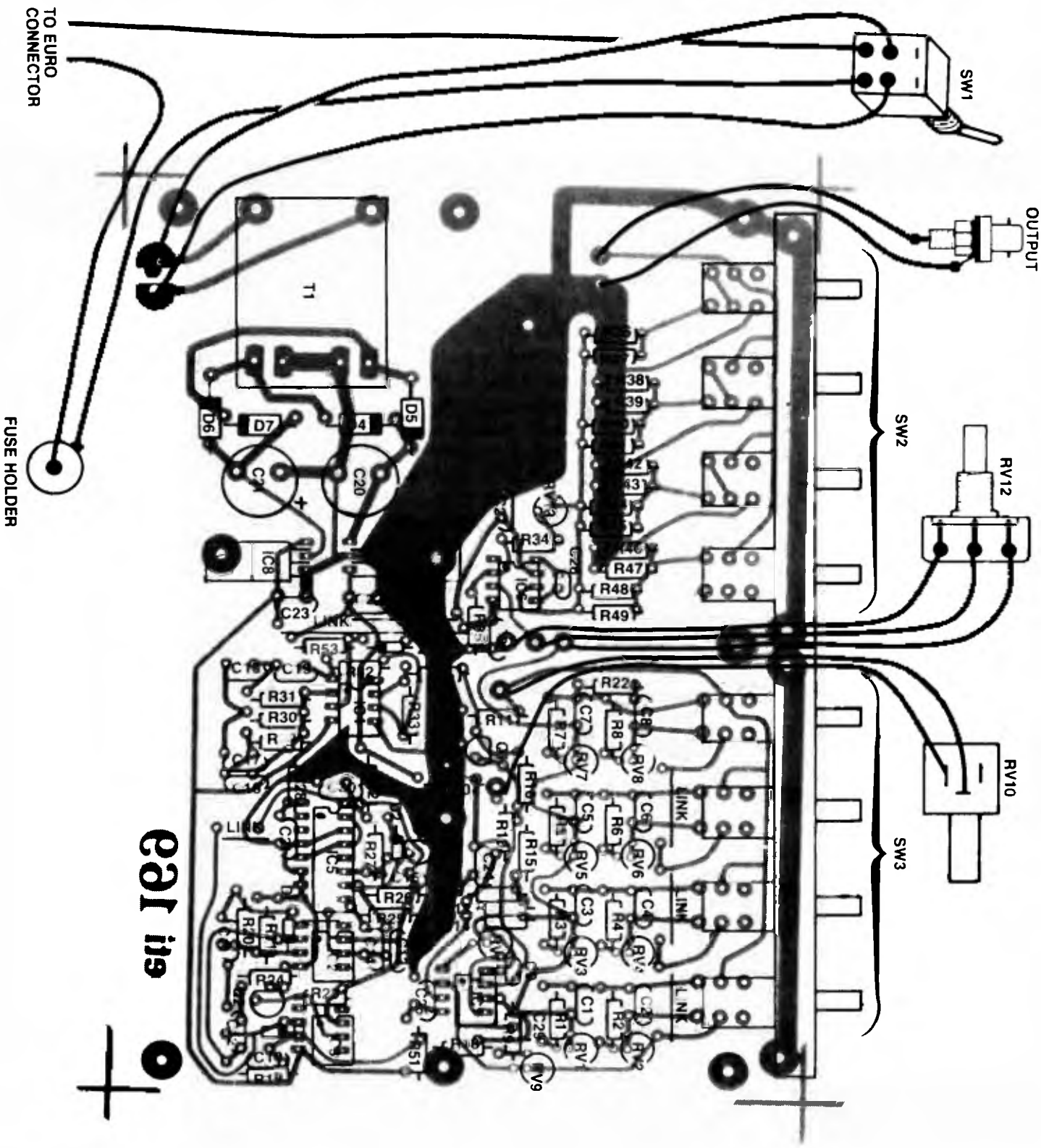
* *see text for types suitable*

Semiconductors
- IC1, 6 ..... NE5534
- IC2 ..... RCA CA 3130
- IC3 ..... LF357
- IC4 ..... RCA CA 3240
- IC5 ..... RCA CD4053BE
- IC7 ..... 7815 + 15 V reg
- IC8 ..... 7915 − 15 V reg
- Q1 ..... 2N5485
- Q2 ..... BC337
- Q3 ..... BC327
- D1, 2, 3 ..... 1N914
- D4, 5, 6, 7 ..... 1N4004
- ZD1 ..... BZX79 C6V8

Miscellaneous
- T1 ..... Ferguson PL30/2.5 VA
- SW1 ..... DPDT mains toggle switch
- SW2, 3 ..... 4-way pc mount switch bank and knobs
- F1 ..... 350 mA 2AG fuse

ETI-169 pc board; 90 x 60 mm piece sheet copper; 120 x 170 mm sheet aluminium; Euro connector; 2AG fuse holder; 2 knobs for pots; 2 x 25 mm pc board spacer tapped at both ends; BNC panel mount socket; 200 x 160 x 70 mm plastic instrument case; Scotchcal front label; mains hookup wire; light hookup wire; assorted nuts and bolts.

Price estimate: $99.50


TO EURO CONNECTOR
FUSE HOLDER
SW1
OUTPUT
SW2
SW3
RV12
RV10
T1
D6
D7
D5
C20
IC8
C23
LINK
R34
R47
R48
R49
R53
R31
R30
R22
R8
RV8
RV7
RV6
RV5
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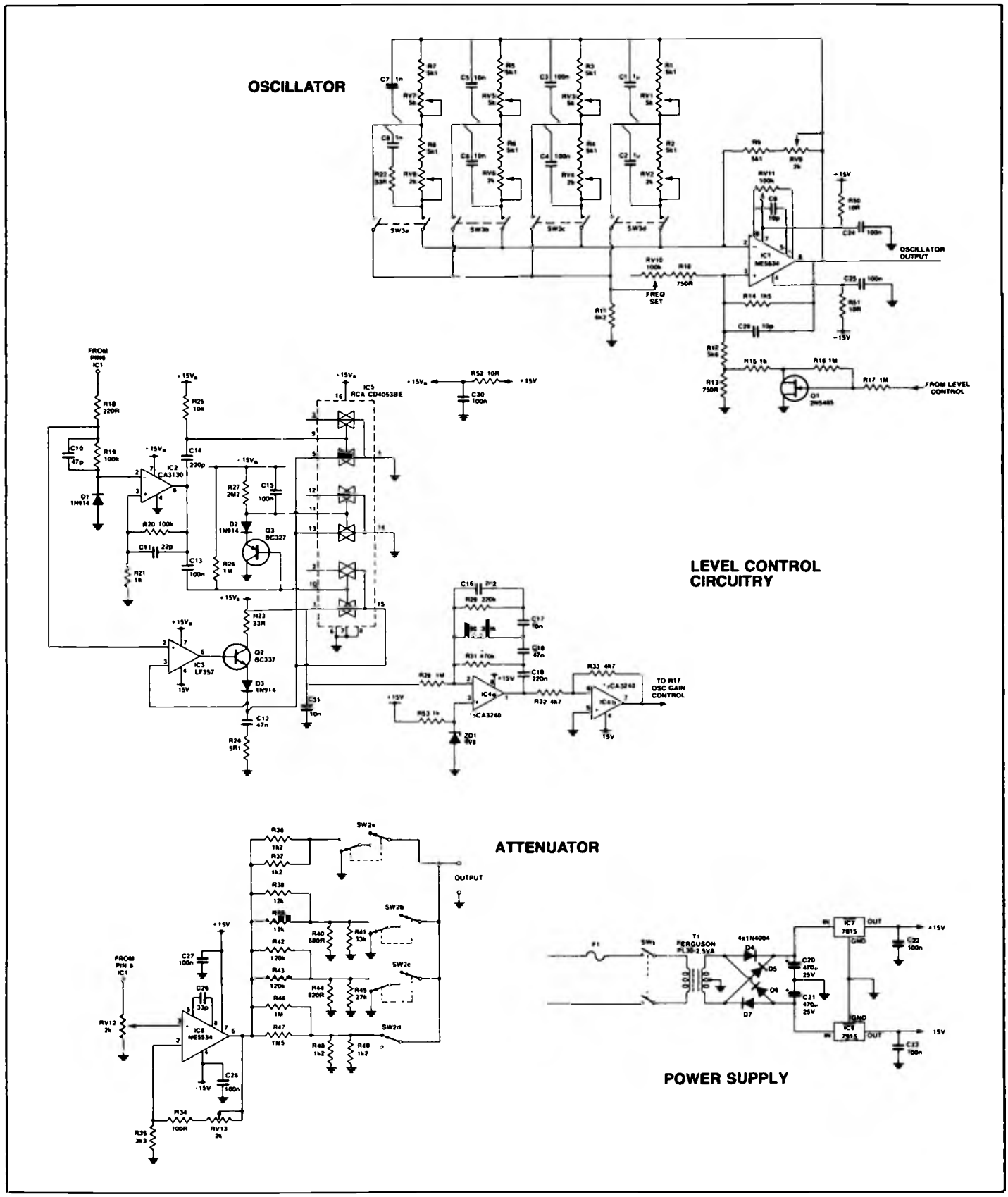
RV9
R6
R15
R2
R20
R24
R26
R51
eti


OSCILLATOR
OSCILLATOR OUTPUT
FREQ SET
FROM LEVEL CONTROL
LEVEL CONTROL CIRCUITRY
TO R17 OSC GAIN CONTROL
ATTENUATOR
OUTPUT
POWER SUPPLY

HOW IT WORKS — ETI-169

The audio oscillator can be separated into four main areas:

(1) the power supply;
(2) the oscillator;
(3) the output buffer and attenuator; and
(4) the level control circuitry which may be further broken down into
  (a) the peak detector;
  (b) the squarer; and
  (c) the integrator — loop filter.

The power supply is a conventional mains operated ±15 volt integrated regulator. The transformer TR1 is mounted on the printed circuit board and has a centre tapped secondary with outputs of ±15 volts ac. With this brand of transformer the secondary is designed to give rated voltage under full load so in the oscillator the voltages on the two filter capacitors C20 and C21 are at about ±24 volts. The current to charge C20 and C21 is provided from the full wave rectifier bridge D5 to D8. ICs 7 and 8 regulate the output from the filter capacitors to provide a clean ±15 volt supply for the oscillator.

The oscillator is based on an NE5534 operational amplifier with both positive and negative feedback. SW1, the frequency band switch, selects one of four RC networks to provide frequency dependent negative feedback through two resistors and two capacitors. The two resistors associated with each of the four networks are made adjustable to make up for the fact that only 10% tolerance capacitors are used. Direct negative feedback is also provided via R9 and RV9, and RV9 allows compensation for the fact that the frequency select potentiometer, RV10, is also only ±10% tolerance.

Negative feedback to preserve the correct conditions for oscillation is provided via R14. R12, R13, R15 and the level control FET, Q1, also form part of the negative feedback network. R16 and R17 ensure that the voltage on the gate of the FET is exactly one half of the gate-source voltage. This minimises distortion introduced by the FET and results in predominantly third order distortion.

RV10 is the frequency adjust pot and by varying its value from 100k to 0 ohms a frequency range of 0.9 to 11 can be achieved. As this frequency variation is proportional to the square root of the resistance it is necessary to use an inverse log law pot to avoid the frequency change being bunched up at one end of the pot rotation.

Both C24 in the negative feedback path and R34 in the highest frequency band select network are to compensate for stray capacitances around the loop and ensure that the correct conditions for oscillation are maintained.

The level control circuitry is fed from the output of the oscillator via R18 which is included to provide some isolation of high frequency spikes generated in the level control circuit. The oscillator output is squared by the squarer IC2 and its associated components. R20, R21 and C11 provide positive feedback for the squarer, which is really only an op-amp operating open loop. As IC2 and the circuitry it drives is CMOS it is necessary to only power it from +15 volts and ground. The op-amp will not tolerate large negative swings on its input under these conditions so R19 and D1 clip the negative swing at the op-amp negative input. C10 provides phase correction at high frequencies.

The output of the squarer drives a CMOS analogue switch CD4053. This switch has three sections, one of which is used to switch the error signal to the loop integrator and the other two are used to control the peak detector reset function.

The peak detector is formed by IC3 and its associated circuitry. IC3 is used as a non-inverting voltage follower with a transistor-diode in the feedback path. To understand how the peak detector works, first consider that C12 has no charge on it. This means that the voltage on the negative input of IC3 is zero volts. As the voltage on the positive input is taken positive by the oscillator output, the output of IC3 will also go positive turning on Q2 and forcing charge into C12 via diode D4. D4 is only included as the reverse bias breakdown of a transistor emitter base junction is normally only 6 or 7 volts and in theory could be left out (in practice it can't). Thus feedback is provided around the op-amp through the transistor and the negative input is held at the same voltage as the positive input. In the process C12 is charged to the same voltage as the positive input. R24 is included in series with C12 so the op-amp doesn't have to drive a purely capacitive load which makes the loop unstable.

When the input from the oscillator reaches its peak value and starts to swing negative again the transistor-diode prevents charge being removed from the capacitor and C12 is left charged to exactly the peak value of the oscillator output. The capacitor is left charged while the oscillator output swings through the complete negative part of its cycle and starts to come positive again. When it passes through zero volts positive going the squarer output IC2 pin 6 switches negative. This sharp edge is differentiated through C14 and R25 to produce a narrow negative spike on the input of one of the analogue switches. This turns on the analogue switch IC5 pins 4 and 5 and partially discharges the peak detector capacitor C12 ready for the next peak detection cycle.

The resultant voltage on the peak detector is thus a dc voltage equal to the peak ac value of the oscillator output with small negative steps every time the oscillator output crosses zero positive going.

A second section of the analogue switch is driven directly from the squarer output such that pins 1 and 15 are on during the negative half of the oscillator output and off during the positive half. Thus when the peak detector output is stable the analogue switch is on and when it is being reset it is off.

One problem that exists with this type of level control circuit is that it is possible for the oscillator to stop running because the gain control is set too low. If the peak detector has been charged to a high voltage by a transient then, as the oscillator is not running, no reset pulse is generated from the squarer output and the oscillator cannot start. To prevent this C15 is continually discharged to ground by the squarer output if it is running by Q3 and D2.

If the squarer stops running or fails to start then R27 charges C15 to the positive rail and turns on the analogue switch pins 13 and 14. This completely discharges the peak detector. At the same time the squarer input to the analogue switch (pins 1 and 15) is ac coupled through C13 and R26 and thus under no signal conditions IC5 (pins 1 and 15) is turned hard on. This ensures that the oscillator will always get a 'kick start' if it fails to start normally.

The loop integrator is formed by one half of IC4, a MOS input op-amp. The input to the integrator is from pin 1 of the analogue switch which is at the peak detector output voltage for half the time and open circuit for the other half. The positive input of the op-amp is set to a reference voltage by the zener diode, ZD1, biased by R29.

A rather complex feedback network is formed around the op-amp by capacitors C16, C17, C18, C19 and resistors R29, R30 and R31. All these components are necessary to preserve the correct gain/phase conditions for all oscillator frequencies and conditions. The most important feature of the network is that C19 has no resistor in parallel with it and hence for low frequencies the amplifier acts as a pure integrator. This means that given sufficient time the dc voltage at the peak detector output will be adjusted by the loop to be exactly equal to the reference voltage no matter how other conditions in the loop vary.

The output of the loop integrator is inverted by the second half of IC4 with resistors R32 and R33. This is because the FET, Q1, requires an increasing dc voltage to reduce the gain and preserves the correct dc operating conditions.

The output buffer amplifier is formed by IC6 and is a simple non-inverting amplifier with adjustable gain so the correct output level can be set. RV12 is the level adjust potentiometer on the front panel which allows the oscillator output to be adjusted from maximum to nothing and RV13 in the feedback is the fine adjust to preset the amplifier gain. The output of IC6 drives three 'L' pad attenuators and a series resistor in parallel to generate four outputs, all of which have a 600 ohm output impedance and output levels of 0, −20, −40 and −60 dB referred to the output of IC6. One of these four outputs is selected by SW2 and connected to the output terminals. SW2 is connected in a 'T' configuration with the centre of the off switches connected to ground to minimise capacitive coupling of the higher level outputs to the low level output.

being coupled into the output. There were three ways that this could occur. The first was that there was hum on the power supply lines but as the crud in the output was 50 Hz this tended to rule it out. Any unfiltered and regulated grot on the rails would be at 100 Hz (full wave rectifier bridge). Also a quick check showed the rails were as pure as the driven slush.

The next way was through some capacitive coupling from the mains area to the oscillator circuit. As the problem seemed to occur only for the lowest frequencies where the frequency set pot has its highest resistance, this seemed most likely. Capacitive coupling is a high impedance effect which is, praise be, easy to stop. By holding my hands around the oscillator I found that I could snuff the coupling with ease. It appeared that I was getting capacitive hopover from the mains wiring to and from the ▶

switch and the high impedance oscillator circuit. Annoying but not disastrous. If it had been stray magnetic fields from the transformer it would have meant deep trouble; an electrostatic field will be stopped by almost anything but a magnetic field takes kilos of iron.

To fix it I cut a piece of sheet metal to fit in the bottom of the box so it covered the complete area under the oscillator. This must include the area under the switch bank right up to the front panel. It should extend from the centre of the box right to the left hand edge. I then completely removed what was left of the unwanted mounting pillars with a hammer and sharp wood chisel and fitted the screen to the case. I connected a piece of wire to the screen and brought it out so I could earth it and reassembled the oscillator. About a 10 dB improvement but still not nearly good enough!

I found that holding my hands over the oscillator part of the circuit still had a very marked effect so a screen above the circuit was needed too. I mounted two 1" spacers off the board in grounded areas and cut a piece of aluminium so it completely covered the top of the board, with a notch out of one corner to clear the transformer and filter capacitors. When I screwed it down there was considerable improvement but still not good enough.

If a piece of metal was held down the left hand side of the box near the oscillator frequency select elements, it helped a bit so I bent up a small bracket to protrude down 25 mm from the top screen, extending from the front edge of the screen to the centre of the side where there is a major mounting pillar. This was easily attached with two of the self tappers that hold the board down. Another test and almost good enough!

After a few more magic gestures with my hands the last culprit was found. The field was coupling into the frequency pot itself which is visible above the screen. A bit more quick work with sheet aluminium and a little box was screwed in place around the pot. In case you have some trouble getting the sheet aluminium, I used a cheap oven baking tray that was on special for a dollar — it seemed to be pretty good stuff too! This completed the screening and got the hum down to acceptable levels. Even if you chose to use a metal instrument case it would still be necessary to do the top part of the screening as the mains wiring and the oscillator are inside the same box.

After you've gone through all the hassles of making screens as above it should be a snip to screw the board in place. Wire up the frequency select pot *using as short a wire as possible*, the output level pot and the mains wiring to the switch. The mains connection on the rear panel was through an IEC socket so if some oaf trips over the mains cord it just pulls the plug rather than ripping the cord out by the roots. Both the mains IEC connector and fuse are mounted off the rear panel and holes have to be cut for them. It's a good idea to cut the fuseholder hole just the right size and cut the locating notch in the side so it cannot rotate. *All mains wiring connections should be securely made by looping the bared end of the wire through the terminal tag then soldering it.* All connections should be completely insulated as you'll be the one to cop it if they aren't. The final result should look pretty much as shown in the photo. If this is all OK, remove the top screen and the unit's ready for final test.

More alignment and testing

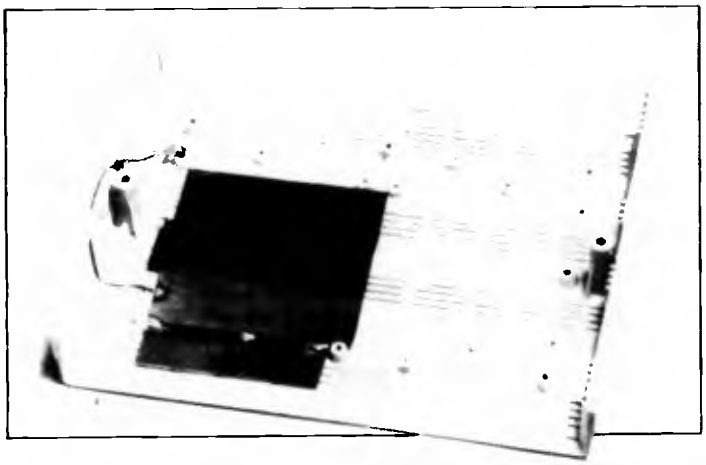
Final alignment follows almost exactly the same routine as laid out in the preliminary testing except that it's a bit easier as the oscillator is working. You'll probably notice things need a bit of tweaking as the stray capacitances have changed. If the FET control voltage is allowed to go much further than −2 volts then the third harmonic distortion will start to rise. It will also be noticed that when the frequency pot is rotated from one extreme to the other a dc offset will appear in the output. To remove this adjust RV11 next to the oscillator op-amp until there is no discernible shift over the entire range.

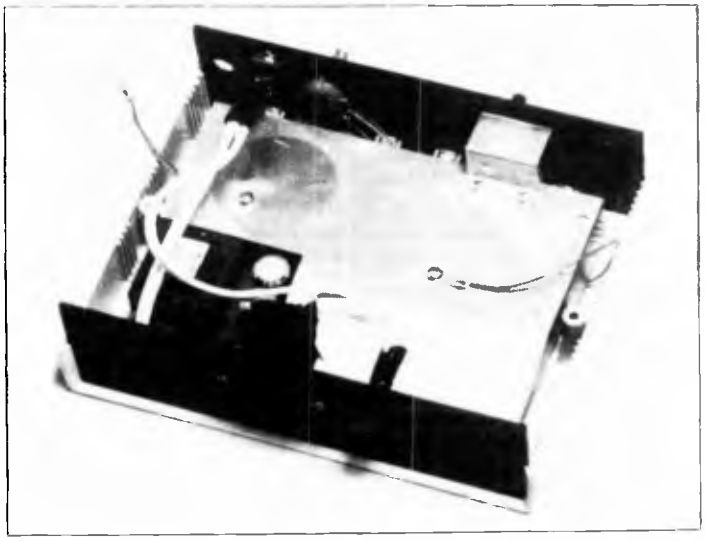
The only adjustment left to be made is to set the output level. To a certain extent this is a matter of choosing the units you like to work in. My choice was to terminate the output in 600 ohms then set the level pot so the maximum level out was +12 dBm or just a shade over 3 Vrms. 0 dBm is a very commonly used reference level in the audio industry and is exactly 1 mW into 600 ohms or, in volts 0.775 Vrms. The oscillator is capable of putting out up to 4 Vrms or +16 dBm.

At this stage the top screen can be screwed into place and the small cover screwed over the pot. It has to be put on afterwards but I imagine you've discovered that already! Screw on the top cover, attach knobs to the two pot shafts and the unit is ready to have the front panel marked. To calibrate the frequency pot set the knob on the pot so the knob pointer's rotation is symmetrical about the vertical axis, then set for far counterclockwise. Select the 900-11,000 Hz range and connect the output to your counter. The counter should read 900 Hz give or take. Mark this point with a pencil and label it. Then proceed up the scale in 1000 Hz increments marking and labelling each point. You will probably want finer calibration points between 1000 and about 4000 Hz but above that the scale starts to close up. The number of points you plot is largely a matter of taste and how you want the front panel to look.

Exactly the same procedure is followed for the level pot except that a level meter (or, at a pinch, an oscilloscope) is connected. If you're calibrating in dBm don't forget to terminate the output in 600 ohms. You can then permanently mark the front panel with an engraving tool or dry transfer lettering to give the unit a completed look. The switch banks also need to be labelled in some way too. When this is all done you've added another weapon to your arsenal of electronic weaponry! ●

Below. Bottom of the box showing the piece of sheet metal covering the area beneath the oscillator. Insulation tape is used to prevent shorting of tracks. **Right.** Aluminium completely covering the top of the board with a small bracket protruding down from the top screen stops the electrostatic field. (View from rear of box.)





ETI 1424 VERSATILE GUITAR PRE-AMPLIFIER

Guitar players always place over the top demands on their gear. This guitar pre-amp certainly delivers over the top specifications.

Terry Kee

COMMERCIAL GUITAR AMPLIFIERS do not appear to be getting any cheaper so a good low cost alternative is to build your own. Power amplifier modules are commonly available from your local kit suppliers at very reasonable prices with excellent performance, particularly those published in this very magazine.

The ETI-1424 is intended to provide high quality pre-amplification especially tailored for the electric guitar. The equalizer sections are optimised for the frequency range where the guitar needs them most.

The main features of the pre-amp include a top boost and normal input for guitars, two pre-eq line inputs, bass and treble controls, effects send and return, a sweep eq section, four post-eq line inputs and a master level control. No level control is provided for the line inputs as typical inputs would be drum machines and synthesisers that have their own individual volume controls. This set-up is designed for the all too common situation where there are insufficient amplifier inputs for all the instruments. More often than not, this happens in a rehearsal situation.

The bass and treble are designed to provide maximum cut and boost of frequencies at 100 Hz and 8 kHz to obtain a wide tonal range for an electric guitar. To give a harder edge to sounds, a top boost input is available whereby frequencies above 1 kHz are amplified; at around 10 kHz there is a massive 20 dB of boost! The normal input has a flat response and is excellent for those mellow rhythm chords. A bass cut is built into the input amplifiers IC1a and b as in a live set-up, very low frequencies combined with speaker cabinet resonances tend to muddy the overall guitar sounds, not to mention setting off the cymbols at some resonant frequency! The guitar inputs have a fairly high input impedance of 220 k to ensure that the pick-ups are not loaded and thus obtain maximum sustain. Due to the high input impedance hum pick-up can be a problem, so the jack sockets are wired in such a way that any unused inputs are shorted to ground. No casing details will be described here as it is likely that the pre-amp will be built into the box that houses the power amplifier. A metal box is recommended to minimise hum pick-up.

Many of the facilities of the 1424 can be tailored to your requirements. If you decide that you do not want any pre or post eq line inputs, as an example, then it is simply a matter of linking the relevant inputs to ground on the pc board. A similar procedure applies if you do not want an effects send and receive, simply link the effect send out pad to the effect return pad with some hook-up wire.

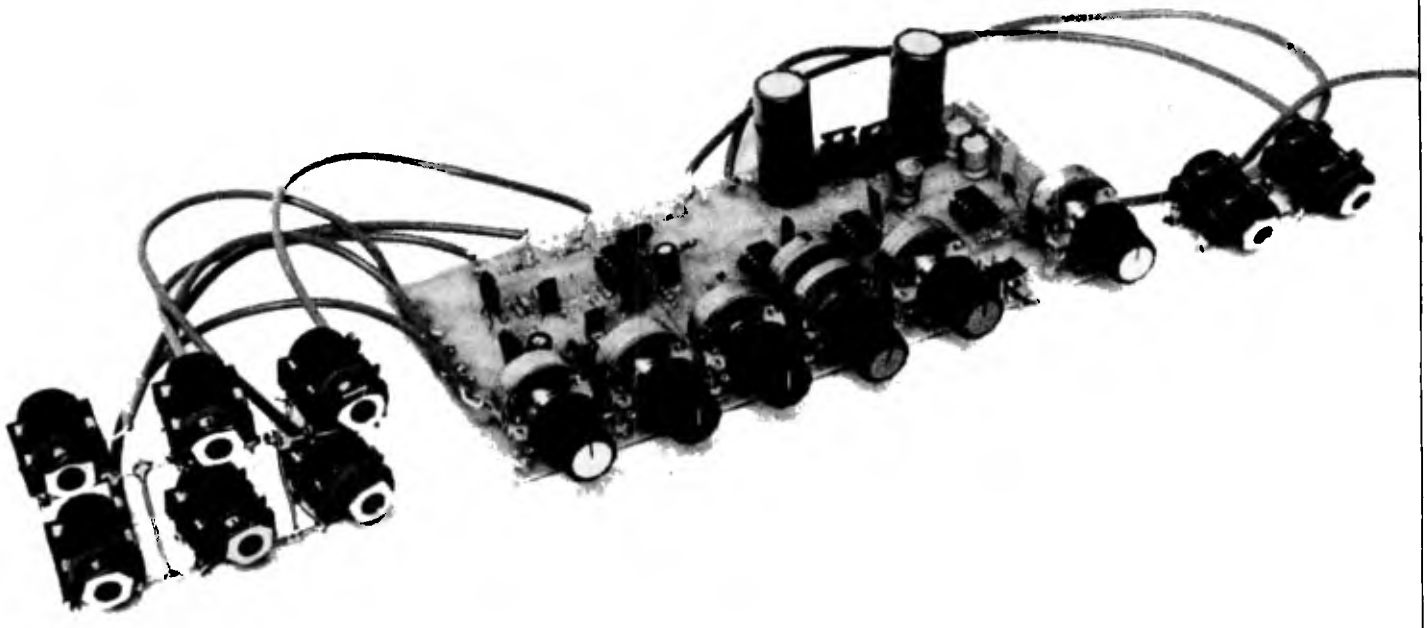
The effects return is fed to a sweep equaliser that has an adjustable frequency and gain control. The circuit is a modified version of the parametric equaliser that appeared in an earlier ETI. A bandpass or bandstop type of response is exhibited with the resonant frequency made adjustable over an extremely wide range of 200 Hz to 8.5 kHz using a single control. The sweep eq supplies a massive 18 dB of boost and −22 dB of cut at the resonant frequency and can be adjusted by the gain control. The Q-factor is fixed and gave good tonal variations with a guitar signal. A bypass switch is included to switch the effect in or out when required. It's useful for pre-setting the eq for that funky toppy rhythm lick! The 1424 derives it's +/− 12 Vdc power from it's on board regulated power supply.

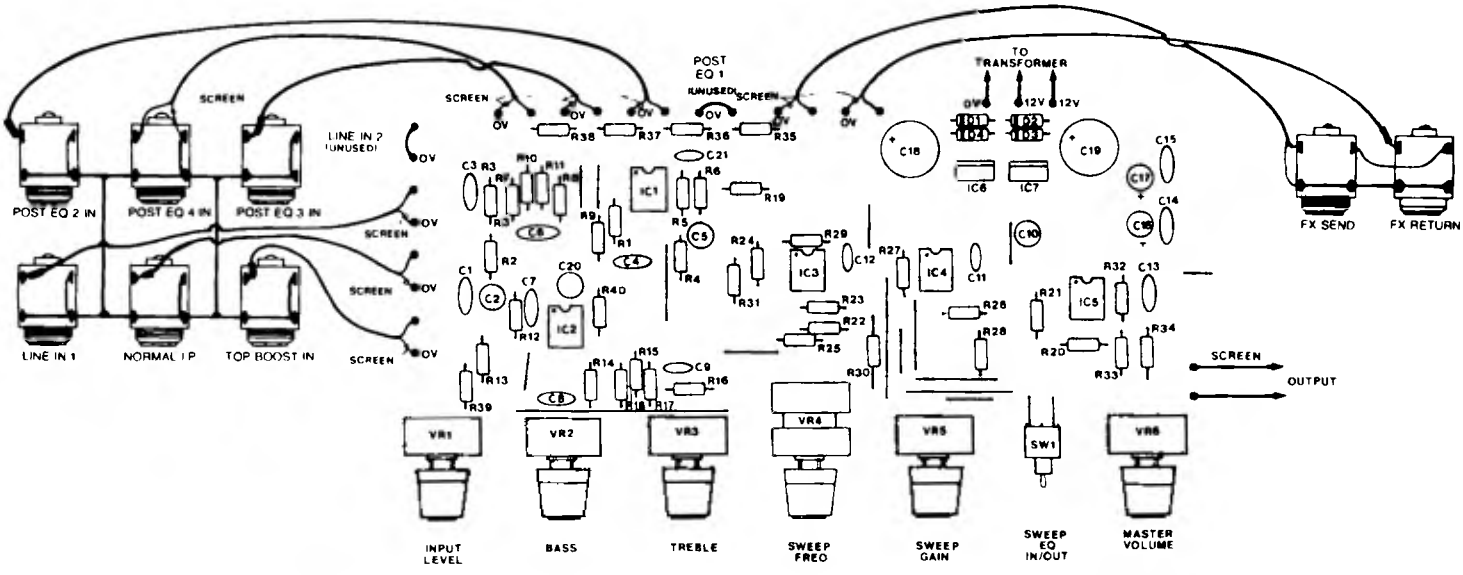
Construction

The pc board is designed to be mounted directly to the front panel of the amplifier box and is fastened down via the nuts on the pots. If you do not want to use pc mount pots and pc mount switches then use the shortest length of hook-up wire to make the connections to these components to minimise hum and pick-up. You will also have to drill some mounting holes on the pc board. Make sure that the holes do not break any tracks.

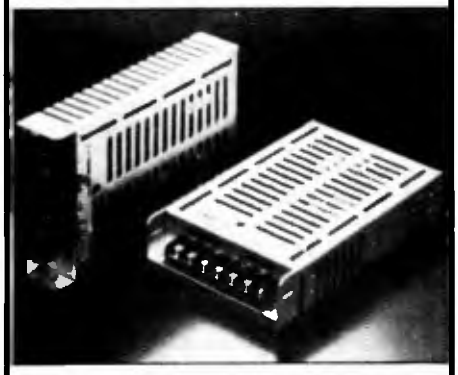
Building up the pc board should not present any problems as the entire circuit is contained on one single-sided board. The first task is to check the board for track breakage and shorts. It's a good idea to go through this process even though you may have obtained the board from a kit supplier. No-one is perfect! Faults will be much easier to spot now than when the board is populated with components. Once you are satisfied it's time to drill the component holes, if it is an undrilled board. Make sure that the holes for the pc mount pots are large enough, a 2 mm drill bit should be adequate.

Construction can start by inserting the links, resistors, capacitors, and ic sockets and soldering them in. Take note of the polarity of the electrolytic caps, refer to




SCREEN
POST EQ 2 IN
POST EQ 4 IN
POST EQ 3 IN
LINE IN 2 (UNUSED)
LINE IN 1
NORMAL I/P
TOP BOOST IN
POST EQ 1 (UNUSED)
TO TRANSFORMER
0V
12V
FX SEND
FX RETURN
OUTPUT
VR1
VR2
VR3
VR4
VR5
SW1
VR6
INPUT LEVEL
BASS
TREBLE
SWEEP FREQ
SWEEP GAIN
SWEEP EQ IN/OUT
MASTER VOLUME

DC/DC CONVERTERS



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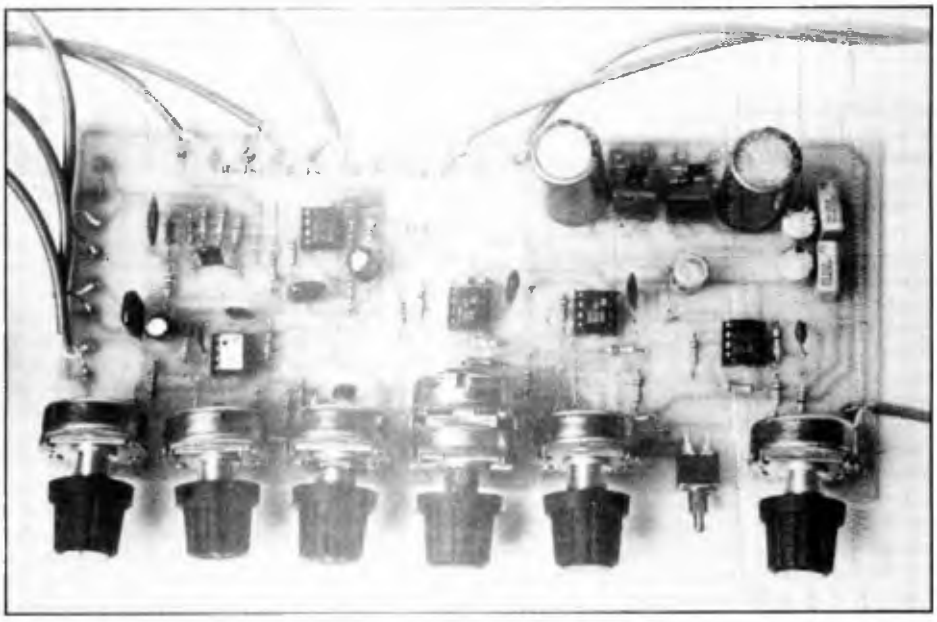


the component overlay. Do not as yet insert the IC's themselves. Insert and solder in the pc mount pots and switch, making sure that they sit firmly and parallel to the pc board. The +/− 12 V regulators (IC6 and 7) are the final components to solder in, note the orientation on the overlay.

Next comes the wiring of the inputs, output, send and return sockets and the mains transformer, if required. After you have decided what inputs you require then it's just a matter of measuring the length of shielded cable to connect to the sockets. Do not forget to link any unused inputs to 0 V on the pc board. It is a good idea to mount the input sockets as far away from the mains transformer as possible to minimise hum pick-up. Also mount the inputs away from the outputs to minimise cross-talk. Use insulated 6.5 mm jack sockets to avoid hum loops. The hot end of the input sockets need to be grounded when no plugs are inserted hence sockets with closed contact are required. The input sockets should have their earth connected together at the sockets with some tinned copper wire. A single connection from the braiding of one of the input screening cable is all that is required to connect the socket earths to the pc board. Refer to the wiring diagram on the overlay. The earth screen of the other inputs needs to be soldered to the 0 V but cut off at the socket end. Make sure that the open ended screen does not short any of the inputs, use some sleeving or insulated tape if you are unsure of your wiring.

The same procedure applies to the effects send and return sockets. Do not forget to link the send out to the return in on

ETI 1424 Parts List

Resistors
All ¼ W Metal film, 5% tolerance

R1,4	220k
R2,6,30,31	2k2
R7,13,40	1k
R8,9,10,11,12,18,20,21,26,28,32,33,35,36,37,38	10k
R3,5,14,15,27	22k
R16,17	4k7
R19,34,39	56R
R22,25	56k
R23	3k9
R24,29	100k
VR1,6	10k log pc mount pot
VR2,3	100k lin pc mount pot
VR4	100k lin pc mount dual-gang pot
VR5	10k lin pc mount pot

Capacitors

C1,4	56n greencap
C2,5	1u/35V bipolar electro
C3,21	82p ceramic
C6	10n greencap
C7,13	560p ceramic
C8	22n greencap
C9,11,12,20	8n2 greencap
C10	3u3/35V bipolar electro
C14,15	100n greencap
C16,17	33u/35V axial electro
C18,19	1000u/35V axial electro

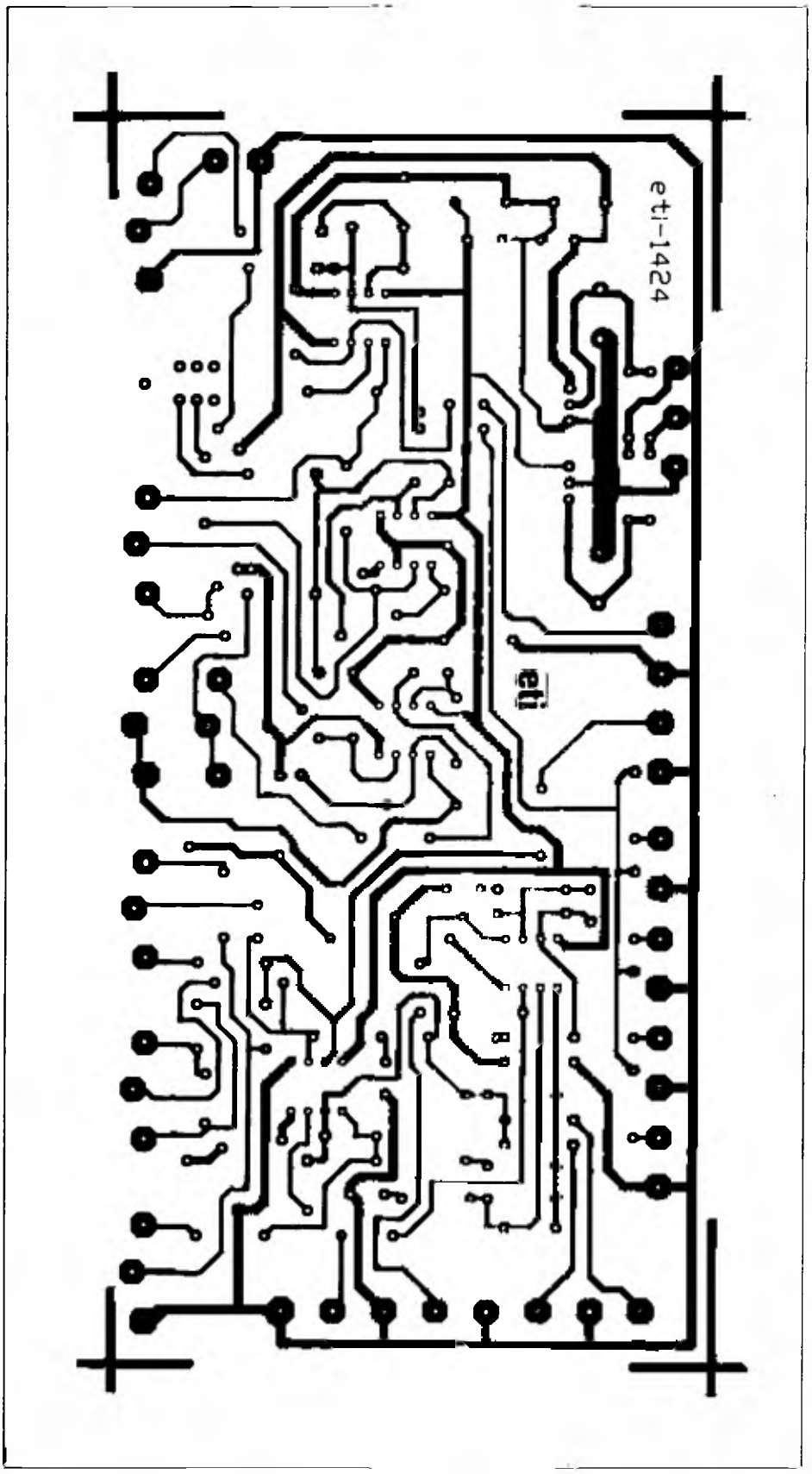
Semiconductors

IC1,2,3,4,5	TL072
IC6	7812
IC7	7912
D1,2,3,4	1N4001

Miscellaneous

SK1 to 11	6.5mm Mono Insulated Jack Sockets (contacts closed when plug is not inserted)
SW1	PC Mount Miniature DPDT toggle
T1	12V-0-12V at 500 mA Mains Transformer

Shielded Audio Cable
5 off 8 pin dil IC sockets



eti
Electronics Today
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the pc board, if you are not using this facility. These sockets are wired in such a way that the signal path is broken when a plug is inserted otherwise continuity is made, refer to the wiring diagram. Use a length of screened cable to connect the output of the pre-amp to the power amplifier.

The mains transformer for your power amplifier may have 12V-0-12 Vac tappings that can power the 1424 directly, otherwise a separate transformer will be required. Ensure that you use mains cable for all connections that carry mains voltage and that the metal chassis of the box is securely earthed. Be extra careful with any mains wiring.

Testing

Once you are satisifed that the pc board is free of solder splashes and dry joints, then it's time to fire up the circuit. Without any of the ic's inserted, apply the power and check that there are +12 Vdc at pins eight and −12 V at pins 4 of the IC's. When it has been established, switch off the supply and insert the IC's. Make sure that they are orientated the correct way, refer to the overlay. Power up again and re-check the dc rails. It would be a good idea to disconnect the output to the power amp for this test. Set the bass and treble knob to midway and the sweep eq to out. Plug in a guitar and check that each input produces an output signal at the output of the pre-amp. Twiddle the tone controls individually and you should hear the difference! Switch in the sweep eq and turn the gain control clockwise to give a boost. Twiddle the frequency knob and you should hear the peak being swept over the frequency range. ●

ETI 1424 How it works

IC1a and b are connected as non-inverting amplifiers with a 20 dB fixed gain set by R2, R3 and R5, R6 for each input amplifier. The sensitivity of these amplifiers can be altered quite easily to suit the different levels of various pick-ups and to match the input sensitivity of different power amplifiers. The voltage gain equation is given by Av1a=1+R3/R2 and Av1b=1+R5/R6, hence to reduce the gain R3 and R5 need to be reduced. These amplifiers are ac coupled via C1 and C4 and the input impedance is set to 220 k for both the normal and top boost guitar input. The output of IC1a is fed to an equalizer network consisting of R7, R8 and C6 that boosts signal frequencies above about 1 KHz and will have a massive 20 dB boost at 10 kHz. The outputs of IC1a and b are mixed in IC2a which is connected as a adder, the two pre-eq line inputs are also summed at this point via R10 and R11. The level can be adjusted via VR1 before it is fed to the bass and treble tone controls built around IC2b. It is an active tone filter with the frequency selective components in the feedback path of IC2b. The bass control has a +/− 12 dB of cut and boost at 100 Hz and the treble control has a +/− 20 dB at 8 kHz. With the tone controls set to midway a flat response within 3 dB can be expected. R40 and C20 provides attenuation at high frequency for stability. The output of IC2b is buffered by a 56R resistor R19 to aid stability when driving capacitive loads.

The effects return is ac coupled via C10 and is buffered by IC5a and provides an input impedance of 10 k set by R20. The sweep eq is based on a standard active state variable filter, built around IC3a, 3b, 4a and b. The centre frequency is determined by VR4a and b, R30, R31 and the capacitors C11 and C12. An extremely wide frequency range of 200 Hz to 8.5 kHz can be obtained using a single pot control, VR4. The Q-factor is set to 4 by R25 and R22 and VR5 allows a variation over the stated frequency range. SW1 allows the sweep eq to be bypassed with an overall unity signal level except at the boost or cut frequency. The eq output is then mixed with the four post-eq line inputs in the summer, IC5b, VR6 controls the main output level of the pre-amp.

The 12 V-0-12 Vac is rectified by D1 to D4 which are connected as a full wave rectifier and smoothed by capacitors C18 and C19. A regulated +/−12 Vdc supply is derived from the 7812, (IC6) and 7912, (IC7) regulators. The circuit draws a dc current of around +/− 21 mA.

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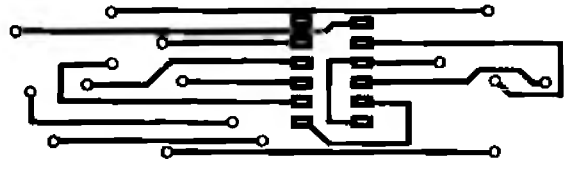

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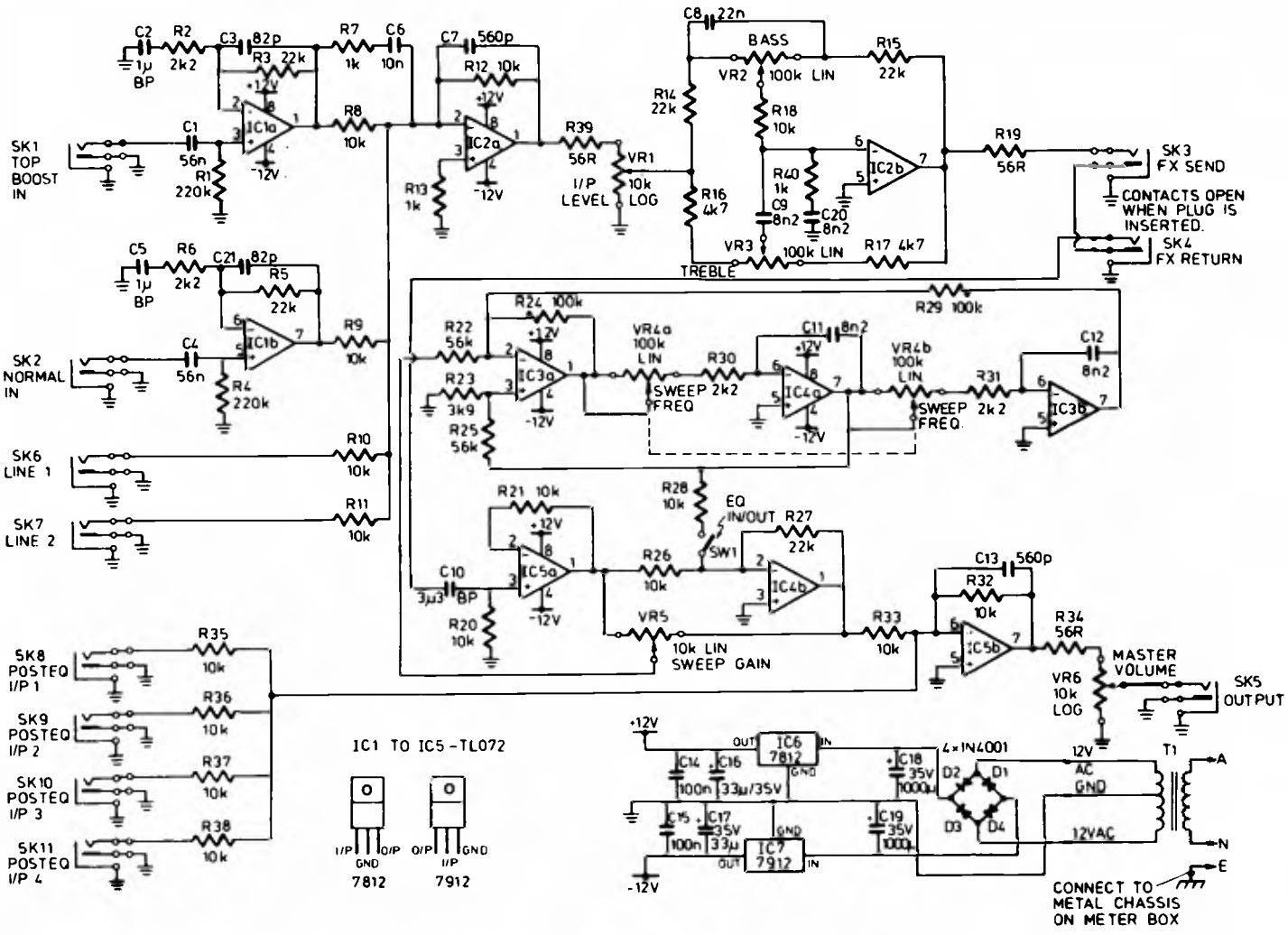
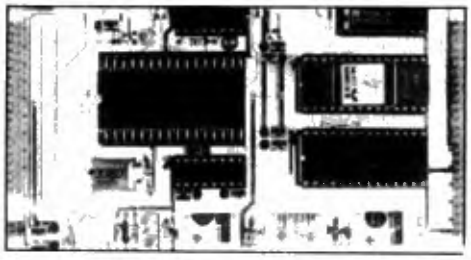


SMART FORTH

EC-IF12 CONTROLLER



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DYNAMIC NOISE REDUCTION SYSTEM

Tell tape noise to hiss off and expand the dynamic range of your tape deck using the ETI-1407 dynamic noise reduction system!

Neale Hancock

DESPITE ITS CONVENIENCE magnetic tape recording suffers from some severe disadvantages. Poor signal-to-noise ratio (around 55 dB), poor dynamic range and distortion (1% to 3%) are pretty common trade-offs for easy recording, playback or erasure. The fight back has come with the various noise reduction systems incorporated into modern tape or cassette players. Unfortunately not all of us have them or are willing to buy new players to get one. Enter the ETI-1407.

The magnificent ETI-1407 dynamic noise reduction system enables you to improve the signal-to-noise ratio of your tape deck by up to 18 dB without treble attenuation. It expands dynamic range allowing you to make recordings from compact discs, and depending on how you use it you can also eliminate some distortion

Wherefore problems

Noise on tape recordings is a relative problem, ie, relative to the audio signal. It is apparent mostly during quiet passages of music as a hiss clearly audible over the music. To make tape noise less noticeable, the music can be recorded at a higher input level, increasing the signal-to-noise ratio by simply increasing the signal level. However, magnetic tape tends to saturate when the input signal level is too high, and the result is as often as not a distorted signal and, in severe cases, a signal which disappears altogether. This effect is referred to as drop-out and is caused by magnetic particles on the tape not being able to accept high signal levels. So back to low input levels.

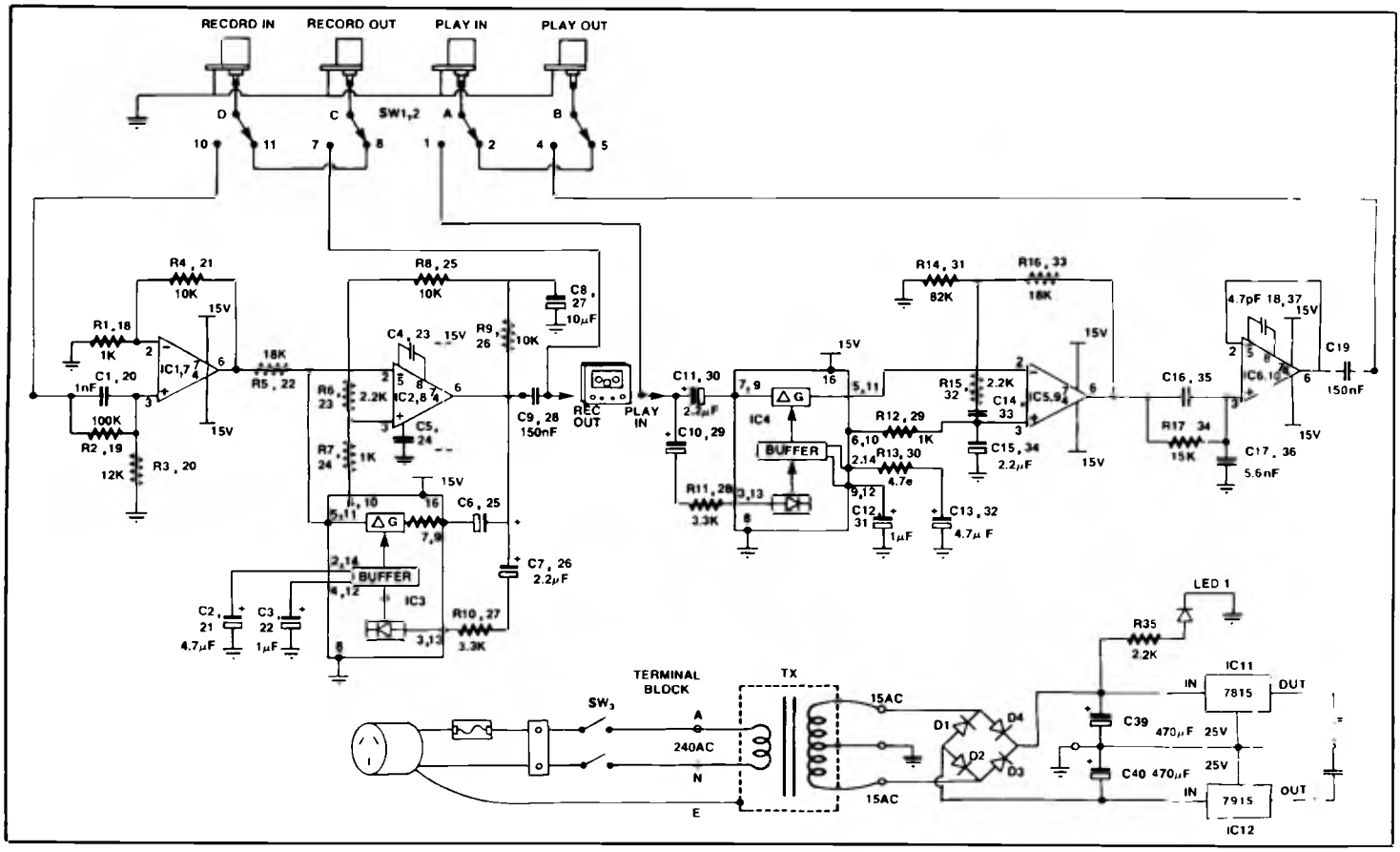
High frequency hiss, the most noticeable form of tape noise, can be removed by turning down the treble control of your hi-fi, right? But that gets rid of all the high frequencies in your music as well. So what is required is a way of removing the high frequency hiss without reducing the high frequency content of your music. One method is to boost the high frequencies as the music is being recorded, then cut them by the same amount when the music is played back.

The theory behind this method of reducing noise runs as follows. In audio signals such as speech and music, low frequency signals have the most energy. Thus you hear the bass sounds of music played in the next room (or next house if your neighbours are headbangers) more easily, because the energy of the bass sounds enables them to travel through walls. Conversely, noise has greatest energy in the high frequency range, which is where the audio signal has its least. So boosting the high frequency signal gives it the energy it needs to overcome the noise introduced by the magnetic tape. Cutting both the signal and noise on playback restores the musical signal to its original form, but with reduced noise.

This method of noise reduction is known as pre-emphasis/de-emphasis and is used in FM broadcasting. A graphical representation of its effect on noise is illustrated in Figure 1.

Whilst pre-emphasis may give the audio signal the boost it requires to overcome noise, it also places greater demands on the limited dynamic range of the tape. The boost given to high frequencies can be as much as 20 dB and when this is added to 90 dB odd of signal (in the case of recording from CD), your humble cassette tape will have a rupture trying to cope with 100 dB of dynamic range! To enable signals with 110 dB of dynamic range to be squeezed onto a tape capable of handling only 60 dB, the signal has to be compressed during recording, then expanded at playback to recover the signal's dynamic range.

So the signal flow for a dynamic noise reduction system runs as follows: input signal is pre-emphasised, then compressed and recorded onto tape; when played back from the tape the signal is expanded then de-emphasised. This sequence is shown in block diagram form in Figure 2. ▶



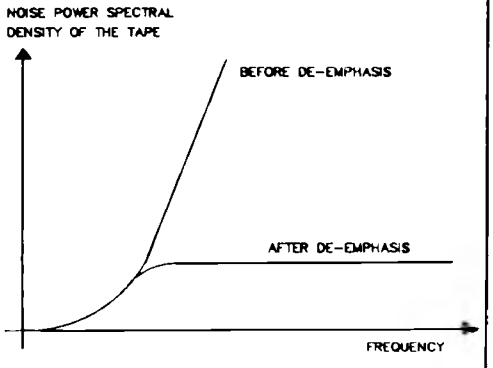


Figure 1. Noise power spectral density/frequency.

ETI-1407 — HOW IT WORKS

As this circuit has two channels there are two part numbers for each component. For convenience sake only the higher value component will be referred to.

IC1 provides 20 dB of pre-emphasis to the incoming signal, the amount of gain is set by the resistor pair, R1 and R4. The combination of C1 and R3 sets the lower breakpoint of the pre-emphasis filter (see Figure 3) while the upper breakpoint is set by R2 and C1.

The output from the pre-emphasis stage goes to the compressor stage which consists of IC2 and IC3. Pin 7 of IC3 is the input to the variable gain cell and pin 3 is the rms detector input. The rms detector and the variable gain cell interact to compress the dynamic range of the signal. The current output from pin 5 of IC3 is the compressor output, which is converted into a voltage via the op-amp IC2. R8, R9 and C8 set the compression ratio at 2:1. C3 sets the attack time of the compressor to 40 ms while C2 sets the recovery time to 200 ms. The output from this stage is recorded onto tape.

The signal played back from the tape is expanded by 2:1 via IC4 and IC5. This expansion ratio is set by R16. Pin 7 of IC4 is the signal input into the expander, while pin 3 is the rms detector input. The output from pin 5 of IC4 is converted to a voltage via the op-amp, IC5. Capacitor C12 sets the attack time constant whilst C13 sets the release time constant, both of these are the same as for the compressor stage.

The de-emphasis filter consists of IC6, C16, C17 and R17. This filter removes the 20 dB boost created by the pre-emphasis filter. C16, C17 and R17 set the cut-off point, and are chosen to match the response of this filter with the response of the pre-emphasis filter. The output from this stage goes to the amplifier.

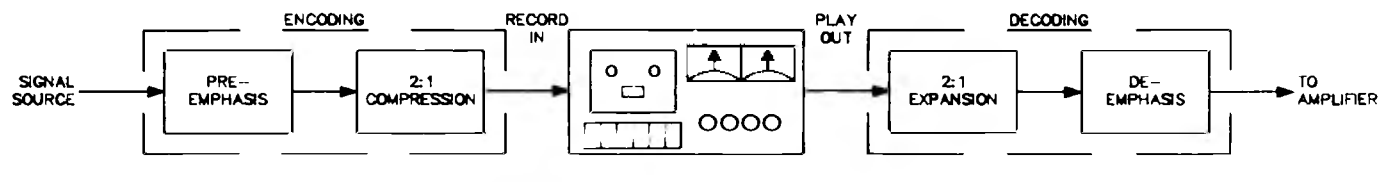


Figure 2. Block diagram of noise reduction system.

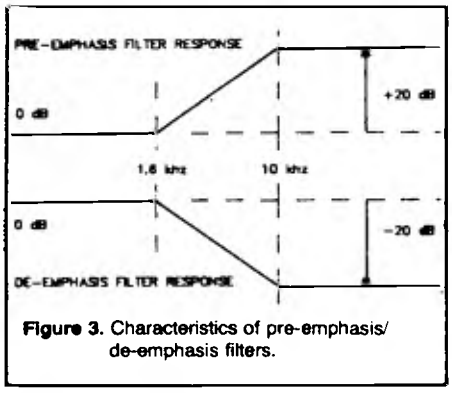
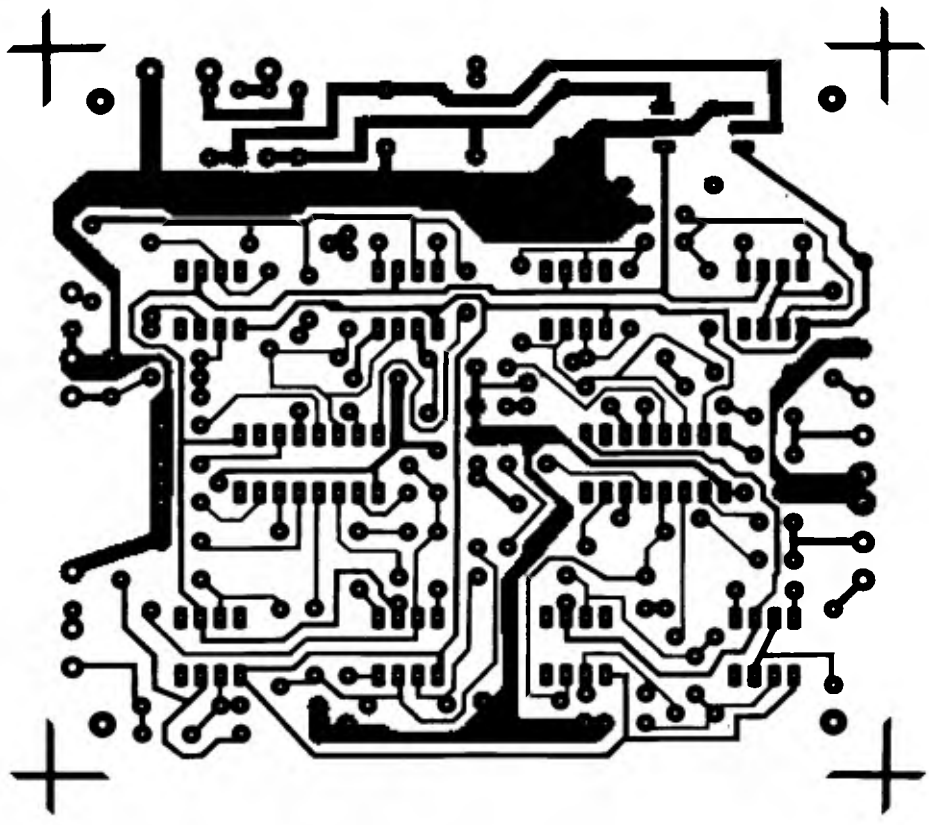


Figure 3. Characteristics of pre-emphasis/ de-emphasis filters.



Circuit

The ETI-1407 dynamic noise reduction system applies 20 dB of pre-emphasis to audio signals above 1.6 kHz. The total signal is then compressed by a 2:1 ratio, which means that a signal with a dynamic range of 110 dB is compressed to 55 dB. The expansion ratio for signals played back from the tape is correspondingly 2:1, then the de-emphasis filter cuts signals above 1.6 kHz. (See Figure 3 for the characteristics of these filters.)

Since the pre-emphasis and de-emphasis filters are both first order and have the same breakpoint, there should be no colouration of the sound passing through the noise reduction system. This is the ideal. In practice the filters do have slightly different breakpoints and there may be a slight peak or dip in the frequency response. To minimize the size of this irregularity, 1% resistors are used to set the breakpoints. In two units which I tested, the mismatch led to a 2 dB boost to the treble above 10 dB which is not detrimental to the recorded music. In effect, it makes up for some of the deficiencies in the tape's frequency response.

The desired amount of pre-emphasis and de-emphasis is applied via first order active filters. NE-5534 low noise op-amps are used to ensure that the system itself contributes as little noise as possible. An NE-572 programmable compandor compresses and expands the audio signal via a variable gain cell coupled with a level detector. To convert the current output from the NE-572 into a voltage, an external low noise op-amp is required.

The NE-572 has a low noise floor (typically 6 μV), a wide dynamic range (110 dB) and relatively low distortion (typically 0.05%). (The noise floor and distortion figures for the NE-572 are much better than for its predecessor, the NE-571.)

Hum and noise contributed by the noise reduction system was measured at −86 dB for hum and −92 dB for noise with a reference signal of 1 kHz at a 0.7 voltage rms. Distortion for the same input conditions was around 0.1%, which is negligible compared to the distortion contributed by the tape deck. With the noise reduction system connected up to a tape deck, noise was reduced by around 16 dB. This level made it possible to achieve a dynamic range of 74 dB compared to a 58 dB dynamic range obtained without noise reduction.

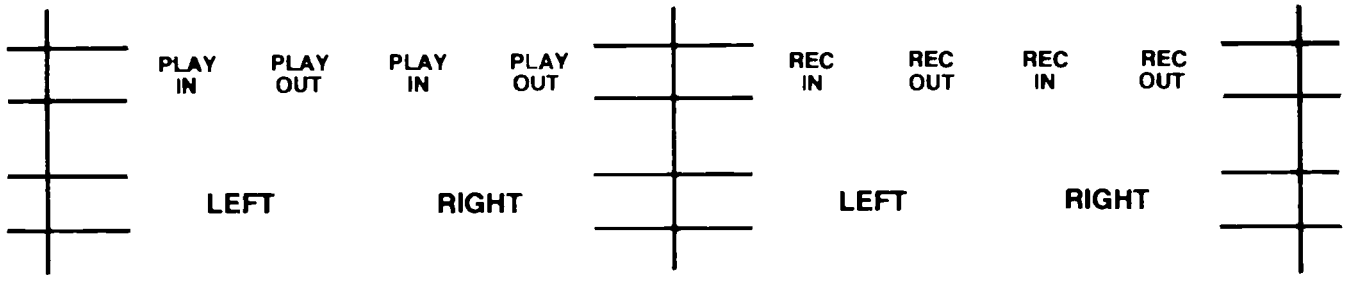
While the ETI-1407 is effective in removing unwanted noise without noticeably affecting the signal, it does have one limitation: signals recorded onto tape via the noise reduction system (encoded signals) can only be played back via the noise reduction system (decoded). If an encoded signal is played back without any decoding then it will hardly be dynamic and will suffer an excess of treble. Alternatively, if a normally recorded signal is decoded, the music will lack treble and be over-dynamic.

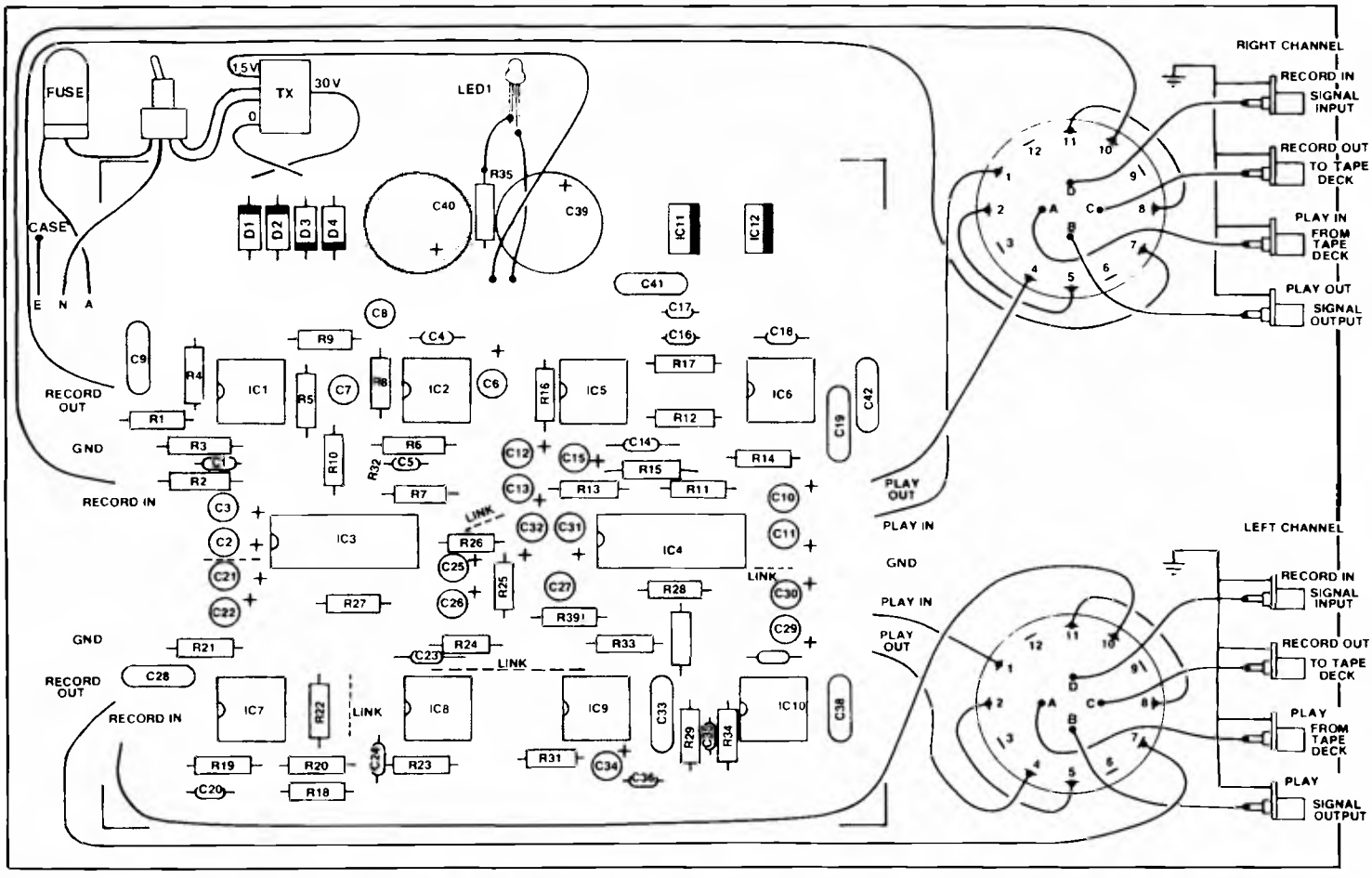
Construction

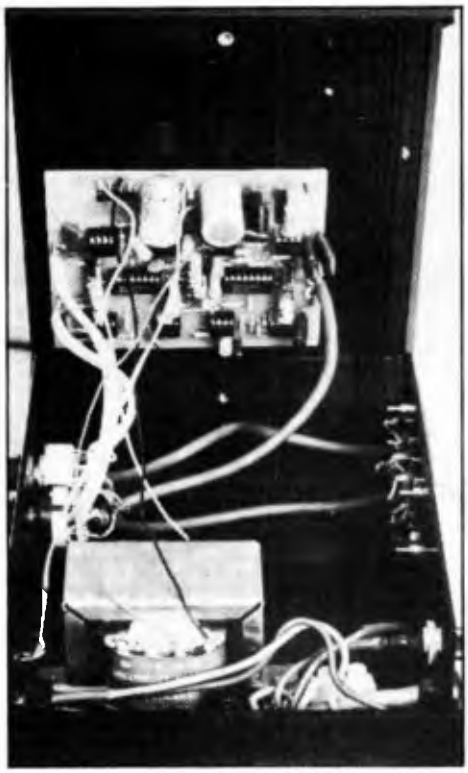
Before soldering anything to the circuit board, check it for defects such as broken or bridged tracks. Begin construction of the circuit board by soldering in the five wire links. Next solder in all the resistors. Since many of them are 1%, be sure to mount them in the correct locations. As the colour coding of 1% resistors can be confusing it is a good idea to check their values with a multimeter before you insert them.

Next mount all the capacitors, but check that the electrolytic capacitors are polarized correctly.

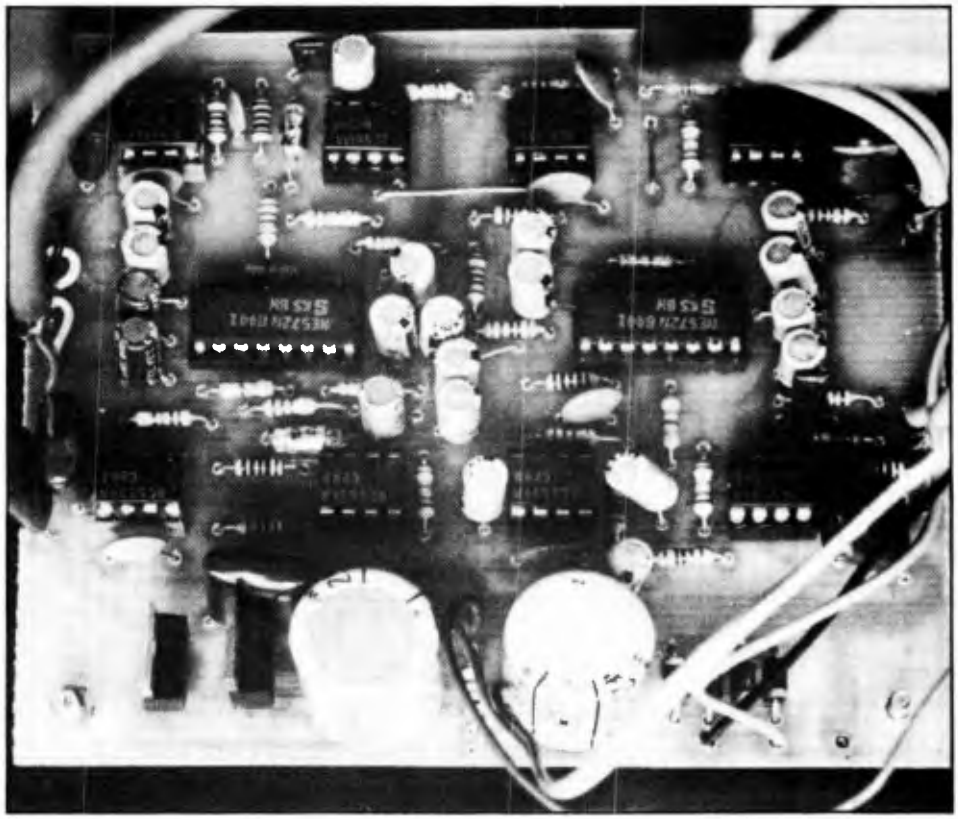
The low noise op-amps (ICs 1,2,5,6,7,8,9 ▶







Parts mounted in the box.



The board.

and 10) can now be soldered in, but check their orientation against the overlay. Make sure they are all orientated the same way. The 16-pin companders (ICs 3 and 4) are not particularly cheap, so they should be mounted in IC sockets. Once the sockets are soldered in, push a compander IC into each of them, but make sure that it is oriented in the same direction as the op-amps. Finish off the pc board by soldering in the diodes, and the voltage regulators (ICs 11 and 12).

Mount the transformer, terminal block, switch and fuseholder in the case. The power cord should be held in place on the rear panel with a cable clamp. The leads from the power cord should be connected as follows: the active (brown) to the fuseholder and from the fuseholder to the terminal block; the neutral (blue) straight to the terminal block; and the earth (green) bolted to the transformer. The reason for connecting the earth lead in this fashion is not only for safety but also to get rid of some of the electromagnetic radiation from the transformer. The active and the neutral are then connected to the transformer via the on/off switch. For the sake of safety, cover the solder joints which connect the transformer to the fuseholder and to the switch with a plastic sleeve or some insulating tape.

The input and output sockets can now be connected to the bypass switches, SW1 and SW2, via two short lengths of four core shielded wire. These switches can be configured for a number of different polling arrangements, but for our needs four-pole two-position will do. The switch can be set to this configuration by changing the position of a ring which fits around the shaft of the switch. The ring has a pin on its perimeter which fits in a hole to select the number of positions required. The bypass switches can then be connected to the pc board via some short lengths of shielded wire. Connect the shield of the wire linking the switch to the pc board. Finally link the transformer to the pc board and connect the LED to the pc board via flying leads.

Before you apply power to the noise reduction system, check the pc board for dry joints and solder bridges. Install a 250 mA fuse in the fuseholder and apply power. The supply rails should be within 150 mV of 15 volts. If they're not, double check the pc board for shorts. Connect the REC OUT port of the noise reduction system to the REC IN of your tape deck and the PLAY IN to the noise reduction system to the PLAY OUT of the tape deck. The REC IN to the noise reduction system is now the input to the tape deck and the PLAY OUT from the noise reduction system takes the place of the output from the tape deck.

The ETI-1407 dynamic noise reduction system can also be used with multitrack recorders but should be carefully monitored to prevent unpleasant overloading effects.

If you require noise reduction for a four track recorder, simply construct two ETI-1407 circuit boards, leaving off the power supply from the second board (specifically, C39, C40, R35, LED1, IC11 and IC12). Then connect the +15 volt, −15 volt and ground lines from one board to another. Both circuit boards can be mounted in the one case and the bypass switches should then be labelled ONE to FOUR instead of LEFT and RIGHT.

Testing

Commence testing by recording a piece of music (preferably with very quiet as well as very dynamic parts), turning the left hand switch to the BYPASS position and the right hand switch to the IN position. Replay the music listening alternatively to the left and right channels, especially in the quiet parts. The channel with the noise reduction should have much less hiss. If this channel sounds more distorted take note of the recording level and make future recordings at a lower level.

If you don't succeed in recording anything on the tape, check the wiring which connects the rotary switches to the input and output sockets and to the pc board. Also check that you have connected the noise reduction system and the tape deck correctly. Since the noise reduction system consists of an encoding and decoding section for both the left and right channels, each section can be checked separately to diagnose the cause of a fault. The encoding section can be checked by inputting a signal into the REC IN socket and listening to it at the REC OUT socket. The decoding section can be checked by inputting a signal into the PLAY IN socket and listening to it at the PLAY OUT socket. ●

ETI-1407 — PARTS LIST

Resistors ..... all ¼ watt, unless noted
R1,7,12,18,24,29 ..... 1k 1% metal film
R2,19 ..... 100k 1% metal film
R3,R20 ..... 12k 1% metal film
R4,8,9,21,25,26 ..... 10k 1% metal film
R5,16,22,33 ..... 18k
R6,15,23,32,35 ..... 2k2
R10,11,27,28 ..... 3k3
R13,30 ..... 4R7
R14,31 ..... 82k
R17,34 ..... 15k 1% metal film

Capacitors
C1,20 ..... 1n greencap
C2,13,21,32 ..... 4µ7 16 V electro
C3,12,22,31 ..... 1µ 16 V electro
C4,5,18,23,24,27 ..... 47p ceramic
C6,7,10,11,15,25,26,29,30,34 ..... 2µ2 16 V electro
C8,27 ..... 10µ 16 V electro
C9,19,28,38 ..... 150n greencap
C14,33 ..... 270p ceramic
C16,35 ..... 820p ceramic
C17,36 ..... 5n6 greencap
C39,40 ..... 470µ 25 V electro
C41,42 ..... 220n greencap

Semiconductors
D1-4 ..... 1N4004
LED1 ..... red, 5 mm
IC1,2,5,6,7,8,9,10 ..... NE-5534 low noise op-amp
IC3,4 ..... NE-572 dual compander
IC11 7815
IC12 7915

Miscellaneous
2 x 4-pole 2-position rotary switch; 1 x DPDT toggle switch; 1 x mains transformer with 0, 15 and 30 volt outputs; case to suit; ETI-1407 pc board; 2 x 4 way RCA panel connectors; 4-core shielded cable.

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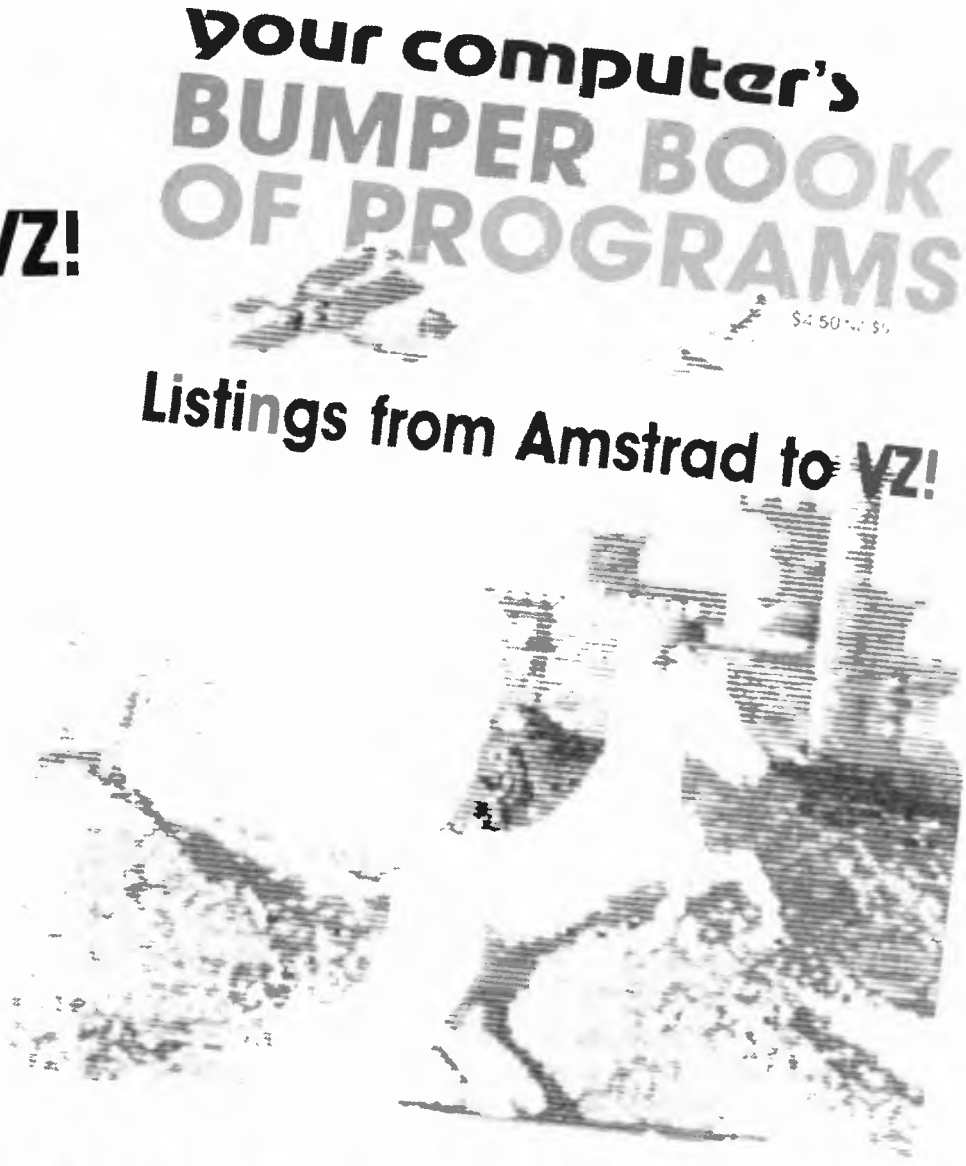


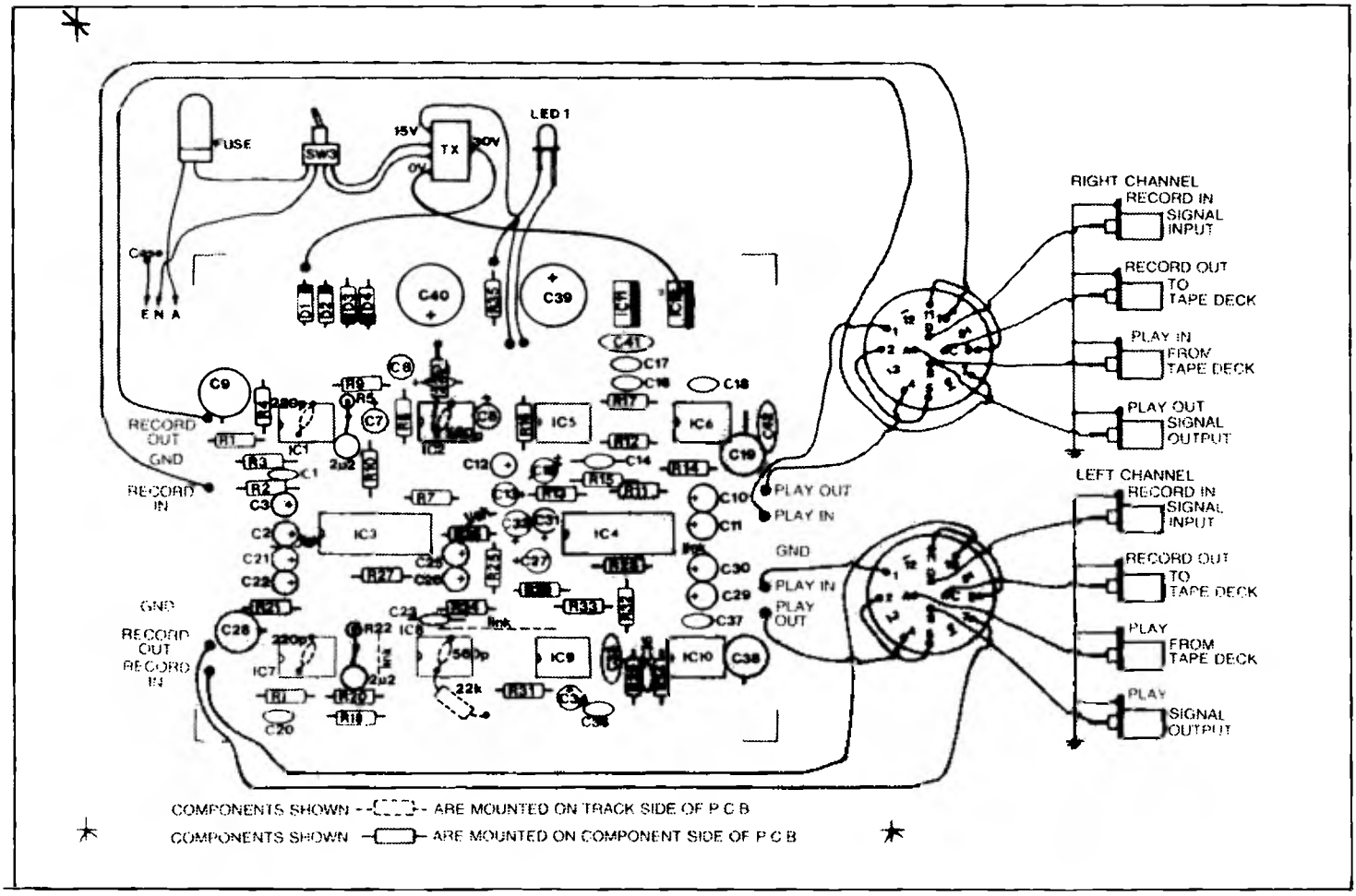
ON SALE NOW AT NEWSAGENCIES

NOISE REDUCTION UNIT

READER FEEDBACK INDICATED that there was a problem with the NR unit (1407) published in December, 1986. We re-opened the file and looked into the matter. If you have built up the project and are experiencing problems like clicking occurring on high frequency transients (particularly with CD players), pumping effects, oscillations, loss of bass frequencies and low frequency instability, then the following modifications should solve it.

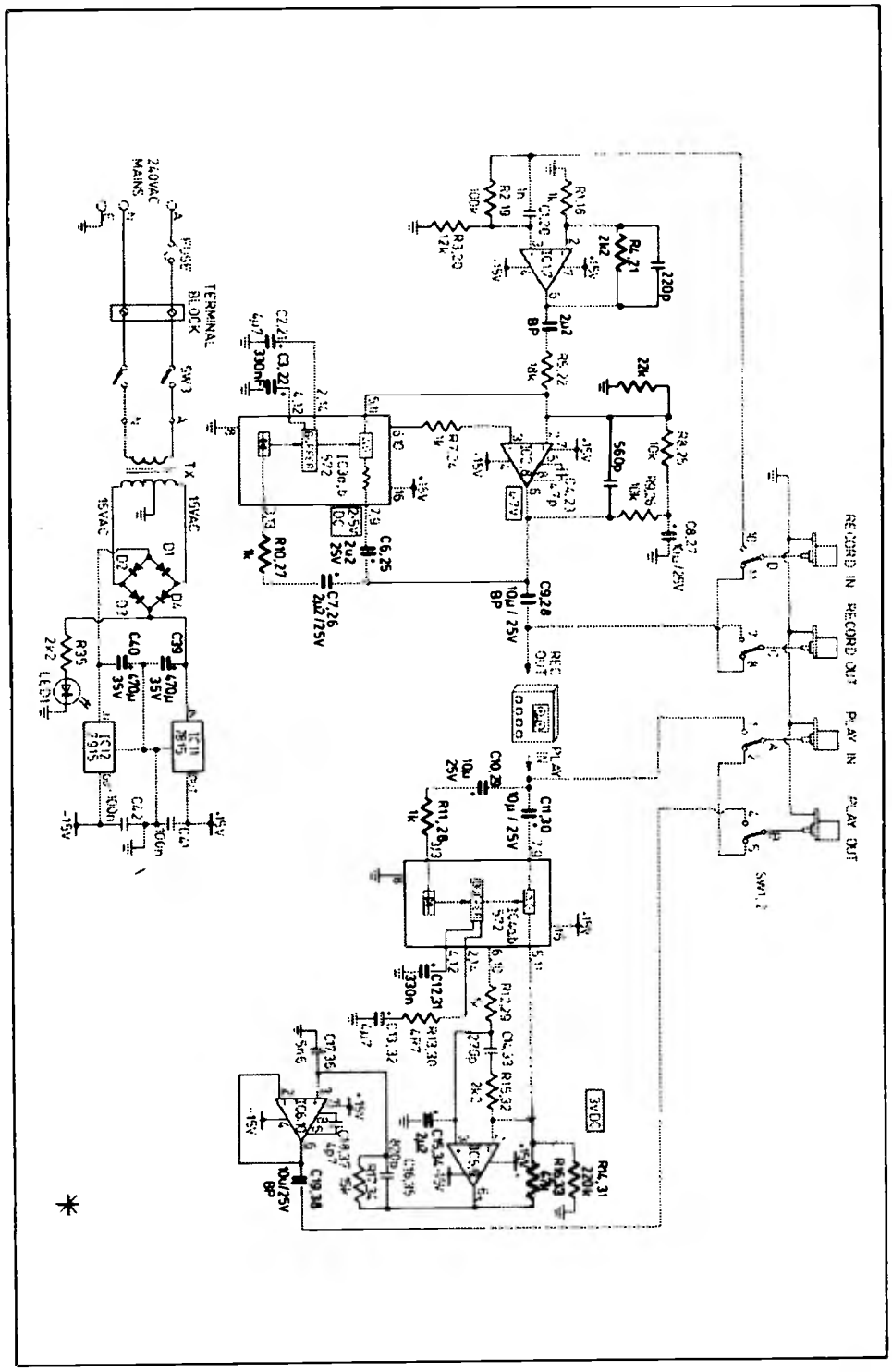
Note that these mods are highlighted in the new schematic diagram and overlay.

a. Change R4,R21 to a 2k2 1% resistor.
b. Change R10,27, 11, 28 to a 1k 1% resistor.
c. Change R16,33 to a 47k 1% resistor.
d. Change R14,31 to a 220k 1% resistor.
e. Change C9,28,19,38 to a 10u/25V Bipolar electrolytic.
f. Change C3,22,12 and 31 to a 330n tantalum. Note the polarity on the overlay.
g. Change C10,29,11,30 to a 10u/25V electrolytic. Note the polarity on the overlay.
h. Use a 470u/35V for the smoothing capacitors C39,40 on the power supply.
i. Take out C5,24 and R6,23 as per the original circuit diagram and leave the pads open circuit.
j. Disconnect the OV hook-up connection from the transformer and solder the wire directly to the OV pins of the 15V regulators on the solder side of the circuit board, see the overlay.
k. Solder a 220p ceramic capacitor across pin 2 and 6 of IC1 and 7. Mount the capacitors directly under the IC's keeping the leads as short as possible. Use some sleeving to prevent any short circuits. Do the same for IC2 and 8 but use a 560p ceramic capacitor.
l. Insert a 2u2/25V Bipolar electrolytic in series with R5 and 22 and pin 6 of IC1 and 7, see the overlay and schematic diagram.
m. Connect a 22k resistor 5% from pin 2 of IC2 and 8 to OV directly on the solder side of the pc board, see the overlay. ●



UPDATE

T. Kee



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CREATING WITH ELECTRONICS PART 7

ANALOGUE FREQUENCY METER

In an all digital world, we divert by presenting a low cost, foolproof, analogue frequency meter. Use it as a tacho, as a partner to the signal generator from part 4 of the series, or as a useful measuring device in general.

Peter Phillips

Digital technology has introduced its own particular forms of instrumentation, usually characterised by a numerical display. Analogue instruments, using a pointer as the readout, have their advantages, including the ability to follow a changing value. As well, due to the different operating principles of a frequency meter, compared to a digital frequency counter, measuring low frequencies is as easy as high frequency measurement. The trade off between the two technologies is accuracy, limited in the case of the analogue device to the initial calibration and the linearity of the meter movement. As well, resolution is limited when compared to a frequency counter, but often a four digit display is overkill anyway.

The frequency meter described in this article has numerous features, including two LED indicators that show whether the input signal is adequate and if the input frequency is within the selected range. The input impedance is around 1M ohm, and voltages as low as 10 mV will often register correct readings, despite the specified input voltage of 30 mV. The meter movement is fully protected, making the instrument very easy to use. Also, if both LEDs are on the probability of a wrong reading is very remote.

The project is designed to complement the audio oscillator presented in part 4 of the series, and uses the same size case to provide compatibility in appearance. The measuring range is from 10 Hz to 100 kHz, and a selectable filter is included to clean up a noisy input. Input voltage limiting circuitry allows a wide range of input levels to be handled, and waveforms ranging from sinusoidal to spikes provide a reliable indication. The instrument could be used as a tachometer, or for any application that must show frequency variations. The circuit is based on the 555 timer, along with numerous diodes, Zener diodes and transistors. To aid the novice, some background theory is included, which complements that presented last month.

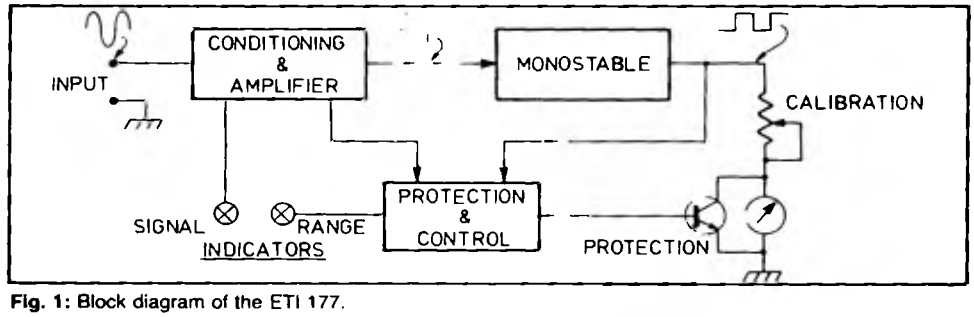


Fig. 1: Block diagram of the ETI 177.

The Circuit Principles

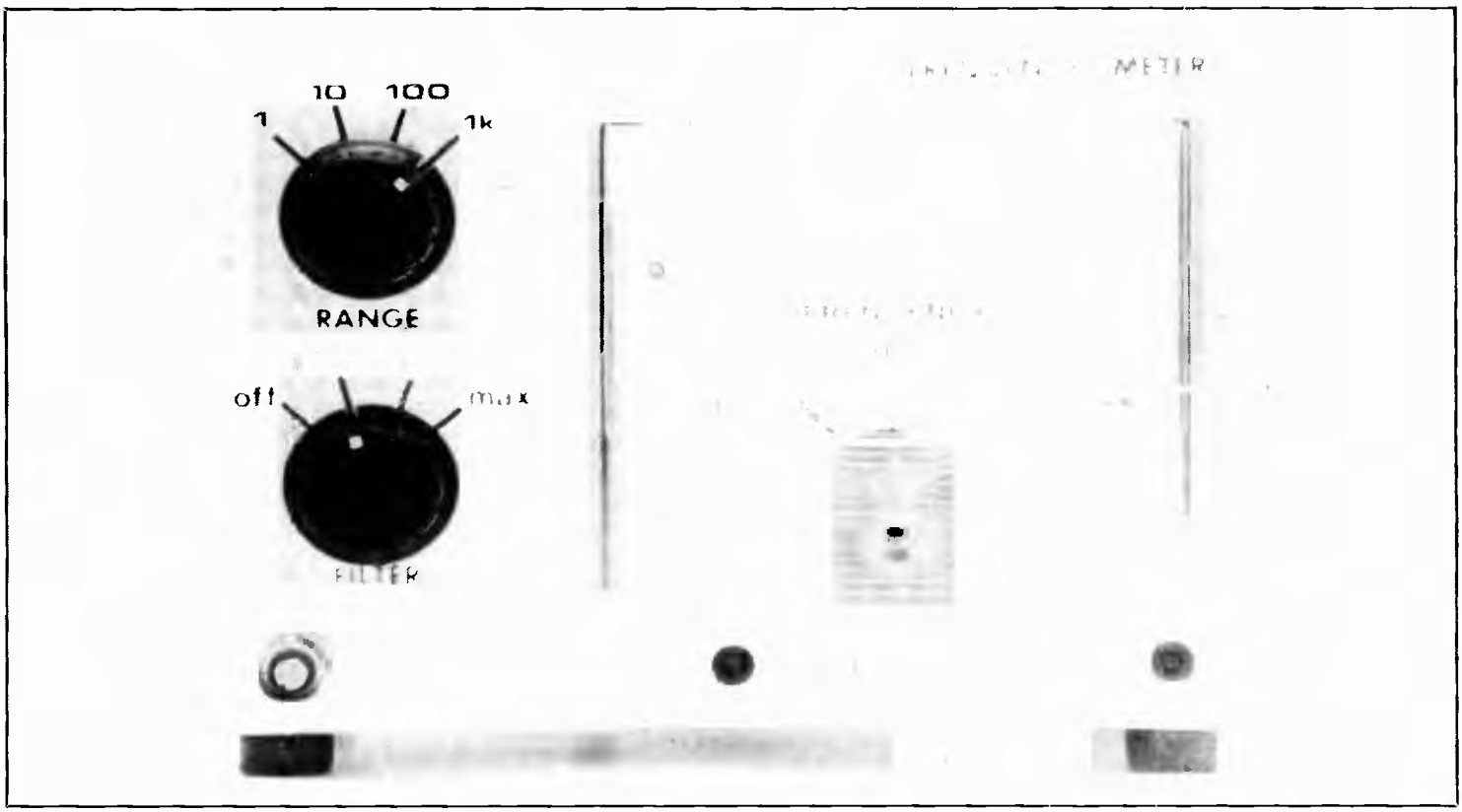
Figure 1 shows a block diagram of the circuit. In principle, the input signal, of whatever waveform, is converted to a series of short duration spikes. These spikes then trigger a monostable multivibrator that produces a fixed duration pulse for each spike. The pulse waveform is then fed directly to a dc meter movement that displays the average value of the waveform. By increasing the input frequency, the pulse rate will increase, producing a higher reading on the meter.

Often, the input frequency may be a total unknown. Frequency counters are notorious for giving apparently steady readings that have no relationship to the correct value. Usually some back-up device such as a CRO is needed if the frequency is to be roughly established, and the counter then made to display the correct value. To overcome this problem, an error detection circuit is included in this project that compares the input frequency to the mark-space ratio of the pulse output of the monostable, and virtually guarantees a valid reading. Meter protection is provided by a transistor connected across the meter terminals and will operate when the pulse waveform has a duty cycle exceeding about 50 per cent.

Background Theory

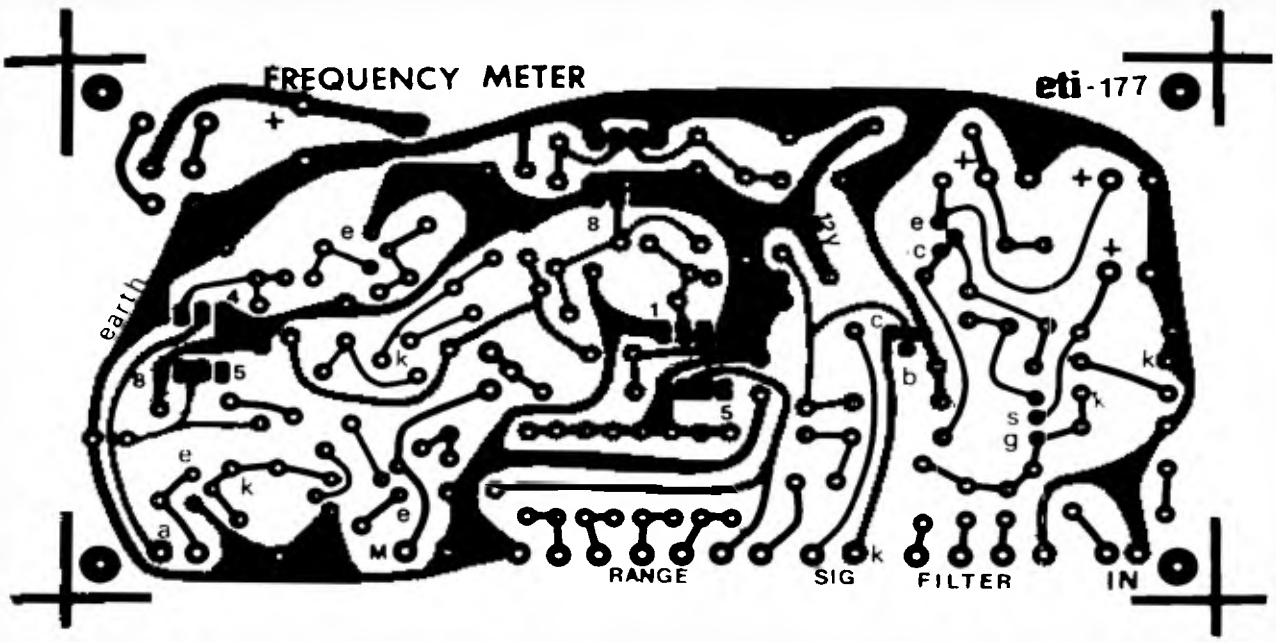
The circuit is basically an analogue switching circuit. Apart from the first stage of the input amplifier, all voltages and waveforms have one of two possible values. While this concept is similar to digital, the principles are still definitely analogue, but based on two levels only. Many analogue circuits use switching to fulfill their required function, such as a switched mode power supply, power control to a motor using thyristors, and so on.

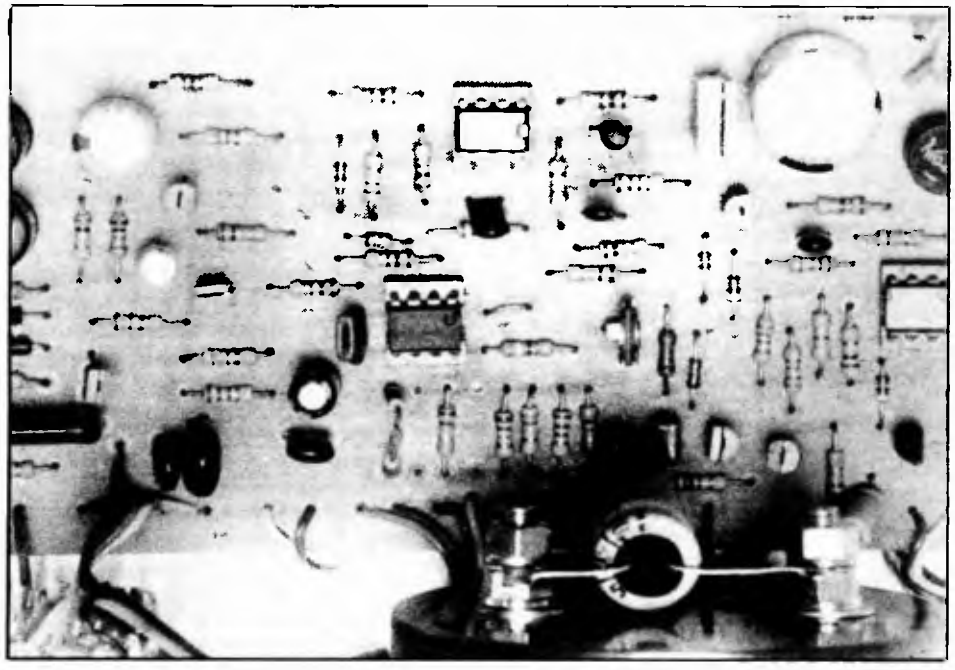
In any switching circuit, devices such as transistors and diodes are commonly used to emulate a conventional switch. As an ideal switch has an infinitely high resistance when off, and zero resistance when on, the electronic equivalent should approximate these conditions. For a transistor, fully on means the voltage across the transistor, ie, between collector and emitter, should be virtually zero. This condition is know as saturation, and is achieved by using a relatively high base current that will cause the required condition despite Beta variations. Keeping the transistor completely off is often difficult, as the



normally insignificant leakage currents introduce problems. To reduce their effect, a current path, usually through a resistor, must be provided between the base and emitter terminals.

Diodes are often used in switches circuits to prevent possible parallel paths between several switching signals connected to the same point. The diodes labelled D_2 and D_3 in the circuit diagram perform this task by effectively isolating the two waveforms applied to the base of Q_4 from each other, while still allowing them both to operate Q_4. In high speed switching circuits, special switching diodes will be ▶





Analogue Frequency meter, circuit board.

specified for their speed and low reverse leakage current characteristics.

Zener diodes are essentially a switching device, acting as an open circuit at voltage below the Zener point, thereafter conducting. Unfortunately, the transition between states is often not as sharp as may be required. This is particularly true for Zener voltages below 10 volts. For example, a 3.3 volt Zener may start conducting at voltages as low as 2.5 volts. Different Zener diode type numbers for the same Zener voltage may have differing switching characteristics, requiring use of the specified device only.

The circuit uses two 555 monostable multivibrators, the operating principles of which were explained last month, along with the shortcomings of some brands of 555s. The type of timing components of any mono are particularly important, to minimise effects due to temperature variations. A polyester capacitor is specified for the timing capacitors, and ideally a high stability, metal film resistor should be used for the timing resistor. Note that a 1 per cent resistor does not necessarily have a better temperature stability than a 5 per cent device, only that its marked value is closer to the actual value.

The term 'mark-space ratio' refers to the time a pulse waveform is in one state compared to the other. Generally, 'mark' refers to the time the waveform is high, and 'space' to when it is low. Another term often used is 'duty cycle', in which the time the output is active (either high or low) is compared to the total time from the commencement of one pulse to the next. A 1:1 mark space ratio is the same as a duty cycle of 50 per cent.

Construction

This circuit could be constructed on vero board, however the pcb layout is recommended to prevent problems caused by long leads and capacitance between tracks. Commence construction by preparing the case. The size of the meter is optional, as sufficient front panel space is provided for most varieties. Use the template supplied with the meter to drill the case, and a nibbler tool to cut the large hole for the meter body. Mount the transformer as shown in the accompanying photos to isolate it from the input amplifier to prevent hum pickup. The LED indicators used in the prototype were pinpoint LEDs mounted in plastic bezels. Any LED will do providing it gives a suitable light output.

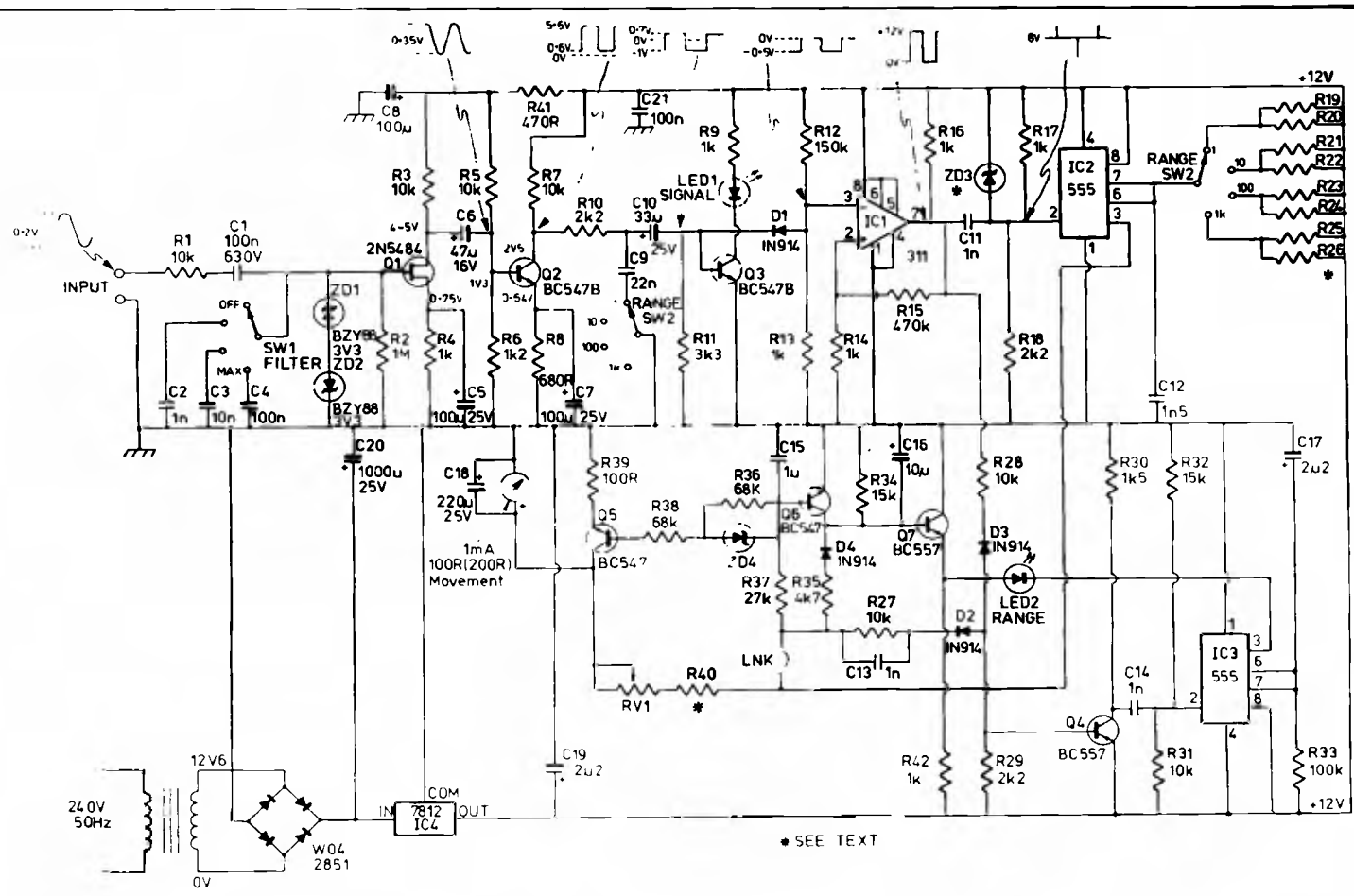
Use the pcb as a template to drill the mounting holes in the case, positioned to clear the protruding devices inside the case. Mount the resistors, (except the calibration resistors, R_{19} R_{26}), the diodes, zeners and wire link first, then proceed with the capacitors and semiconductors. IC sockets make life easier, but are optional. The two wafer switches should be connected with minimum lead lengths, using rainbow cable. To facilitate fault finding, connect the meter and LEDs with leads sufficiently long to allow the pcb and the switches to be held away from to the case. The circuit should operate first up, but Murphy's Law often prevails! After a ▶

ETI-177 How it works

The circuit is in three separate blocks; the input conditioning/amplifier circuit, the output monostable and the protection/control circuit. The first block is as follows. The input signal is coupled to the FET with a 0.1ûF, 630 volt capacitor in series with a 10 k protection resistor, R_1. Filtering of the input is provided by the selectable capacitors, C_2 to C_4, and signal limiting to around $4V_{p-p}$ is achieved by ZD_1 and ZD_2. The input impedance with the filter off is set by R_2, which also connects the gate of the FET to ground. After amplification, the signal is passed to the next amplifier stage, Q_2. For best sensitivity, Q_2 should have a high current gain, and if possible should be selected accordingly by Beta comparisons between available devices. The bias is arranged to cause a virtual square wave at the collector for signal inputs above 100 mV, as a result of the low collector voltage. The signal at the collector of Q_2 is attenuated and clipped by the network comprising R_{10}, C_{10}, R_{11} and the base-emitter of Q_3. Q_3 drives the signal LED, and should operate for inputs above 20 mV. Altering the value of R_{11} will change the input level required to operate the LED. C_9 is connected only on the two lowest ranges and filters noise possible at low input signal levels. Diode D_1 conducts when the signal at its cathode goes slightly negative, and couples the signal to the comparator, IC_1. The comparator has a small amount of positive feedback, provided by R_{15} to produce a Schmitt trigger action, reducing the effects of noise that may cause multiple switching. R_{16} is the pull up resistor for the open-collector output of the comparator.

IC_2 is the output monostable, and is a conventional 555 monostable circuit. The output square wave from the comparator is converted to a spike waveform by the differentiator circuit of R_{17}, R_{18} and C_{11}. As described in part 6, ZD_3 clips the negative going trigger pulse to limit its negative excursion for those 555 ICs that exhibit timing errors on the highest range. The timing components for the mono are the switched resistors R_{19} to R_{26}, and capacitor C_{12}. The values are selected to give a duty cycle of 40 per cent at full scale. (High time 40 per cent, low time 60 per cent.) The output waveform is fed via the series resistors R_{40} and RV_1 to the 1 mA meter movement, which responds to the average value of the waveform. Because the supply voltage is regulated, this arrangement gives a suitable performance. If the supply voltage varies, due to a change of regulator IC_4, recalibration will be needed.

The protection/control circuit has the task of operating the range LED, and protecting the meter against overload. The range LED is driven by IC_3 which is a 555 connected as a monostable. If no trigger pulses are received by IC_3, the LED will be on. Trigger pulses for IC_3 are produced when the input frequency is too high for the selected scale, by NANDing the output waveforms of IC_1 and IC_2 using diodes D_2 and D_3 and transistor Q_4. Figure 2 shows how the circuit works. As depicted, for an in-range frequency, there is always zero volts applied to either one of the diodes. This allows Q_4 to be continously conducting, and holds the voltage across R_{30} at around 12 volts. When the duty cycle of IC_3 exceeds that of the comparator, both diodes will simultaneously



turn off, as both cathodes will be positive for a short time. The transistor stops conducting and the voltage across R_{30} falls to zero. The differentiator of R_{31}, R_{32} and C_{14} produces a negative trigger pulse which fires IC_3, extinguishing the LED. The LED is held off by the succession of trigger pulses from Q_4.

The range LED is also controlled by Q_7 and Q_8 to ensure it is extinguished under conditions not catered for by IC_3. The first is when the output of IC_2 is always low, caused by either no input signal, or a very high input frequency. Q_7, when conducting, will effectively short-circuit the LED, turning it off. To hold Q_7 off under normal operation, the output of IC_2 is half wave rectified by D_4 and C_{16}. This produces a positive voltage at the base of Q_7, holding it off. When there is no output from IC_2, the positive charge on C_{16} is removed by R_{34}, allowing Q_7 to turn on, extinguishing the LED. The second condition occurs when overload is reached. Under extreme conditions, the output of IC_2 may be held high, or at least be operating well above the 40 per cent duty cycle. The integrating circuit of R_{32} and C_{15} will generate a relatively small voltage across C_{15} for duty cycles less than 50 per cent, and start charging it towards 12 volts when the duty cycle is around 60 per cent, as the charge time for C_{15} is now greater than the discharge time resulting in a dc voltage of around 8 volts. When the Zener conducts, it turns on Q_8 which then allows Q_7 to conduct.

So, why the NAD gate and IC_3 you ask? Why not let Q_8 and Q_7 operate the range LED? If this were the case, possible ambiguity with the range LED could occur, caused by half cycling of IC_2 when the input frequency is more than twice the pulse rate of IC_2. Although the components values still ensures a full scale reading, the duty cycle of IC_2 may still be low enough to not cause ZD_4 to conduct. The range LED can then light, making the user think the frequency is within approximately range. We did say its almost perfect, remember!

The last part is the protection for the meter movement, provided by Q_5. This transistor operates the same way as Q_6, and is operated from the same circuit. The emitter resistor R_{39} stabilises Q_5 to allow for the wide range of current gains inherent in the specified transistor type.

A final point is the power supply. In any switching circuit, spikes and noise are generated on the supply rail. These can have the effect of producing false triggering, and generally cause mayhem. De-spiking capacitors are included adjacent to the comparator and IC_2 and C_{19} also aids the regulators due to its physical proximity to both IC_1 and the regulator on the pcb layout. Decoupling for the input amplifier is provided by R_{41} and C_8.

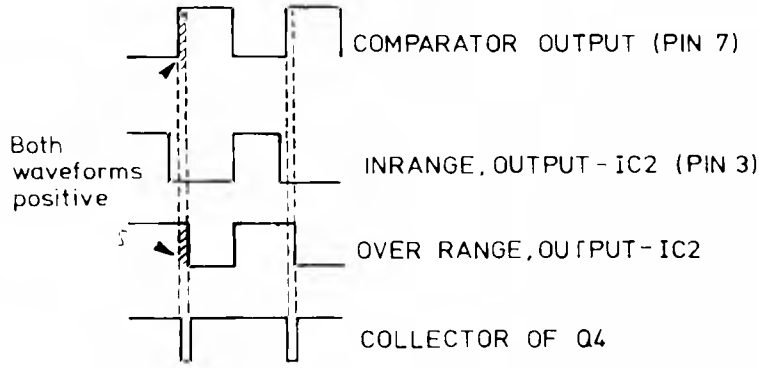
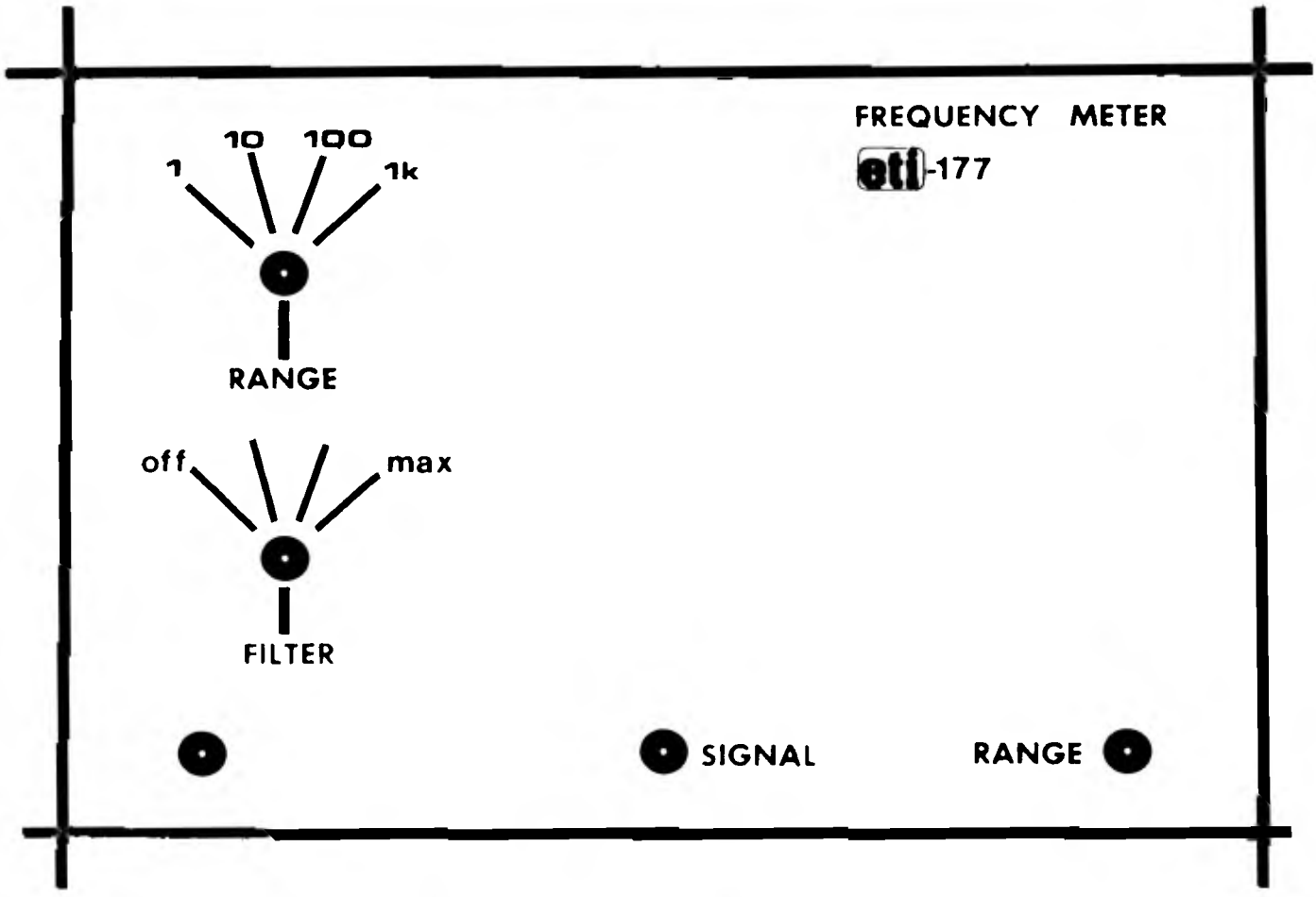


Fig. 2: Control of the 'range' LEDs.



Analogue Frequency meter — internal view

final check for shorts and incorrectly polarised components, connect the transformer secondary, and supply power.

At switch on, nothing should happen; no LED indication or pointer deflection. Touch the regulator and the ICs to ensure they are not overheating. Now connect a 2.2M ohm resistor for R_{19}, and select the lowest range. If everything is working, the meter should indicate, and both LEDs light when a 50 Hz input is applied. If not, note if the signal LED is indicating correctly. If so, go searching around the ICs. The wire link connects all the protection and range LED circuitry, and can be removed to help further isolate the fault.

Calibrating

Once operating, the unit can now be calibrated. Start by applying a 50 Hz input of at least 30 mV. Adjust the value of R_{40} and RV_1 for an exact midscale indication. The value shown for R_{40} is for a 100 ohms, 1 mA movement, and different movements may require this value to be varied. Once set, do not alter the setting of RV_1. Select the x10 range and apply a 500 Hz input. Try a 220 k resistor for R_{21}, but exact calibration can be achieved using a 270 k for this resistor in parallel with an- ▶

other of a higher value. Repeat this for the next decade, with a frequency of 5 kHz and a resistor value of around 22 k.

You will find whether the Zener diode, ZD_3, is needed for IC_2 when the highest range is used. Connect a temporary resistor of 1k8 for R_{25}, and apply 50 kHz. If the deflection is much higher than midscale, the 555 has the propagation problem referred to in Part 6. Try a 10 V Zener diode, otherwise work down in Zener values until the reading is around midscale. Alternatively, use a Fairchild brand 555 (uA555, as specified). Once the decades are in calibration, next confirm that the range LED operates from around 10 per cent of full scale to 1.5 x the decade. On the lowest scale, 10 Hz should make the range LED blink, and it should extinguish at around 150 Hz. The highest scale will have the range LED on between frequencies of around 10 kHz to 150 kHz.

Another check is the effect of the meter protection transistor, Q_5. The value for R_{38} is for the 100 ohm meter movement used in the prototype. If the pointer returns to an on-scale value when the range LED is off, raise the value of R_{38}. If you suspect the protection is inadequate, lower the value. The correct setting will give an overscale reading without obvious distress to the meter movement.

Using the meter

Although billed as foolproof, the relative simplicity of the circuit may not cover all contingencies. In general, trial use has demonstrated that if both LEDs are clearly on, and the meter reading is steady, the correct value is being displayed. With some input waveforms, eg, a short duty cycle square wave, the signal LED may not light, particularly at low frequencies. Sometimes the sensitivity of the input circuit will allow a steady reading without the signal LED being on. This means the input level is below the 20 mV threshold, but is probably still providing a correct indication. Noisy waveforms will produce erratic readings, in which case try switching in the filter. Frequencies above 150 kHz at low voltage levels may produce an apparent reading with both LEDs on. However, the reading will probably vary, and will totally disappear if the filter is switched to its first position.

If the input signal is modulated by a 50 Hz hum, anything is likely. The filter won't remove the hum, and conditioning of the signal may be required. This can be done by connecting a low value capacitor in series with the input, and replacing a resistor value of, say, 10 k across the input terminals. Very high voltage inputs are not recommended, although the input circuit can probably handle up to 240 v rms. Despite these restrictions, we guarantee this meter will be easier to use than many digital frequency counters currently available. ●

PARTS LIST

Resistors — all 1/4 watts 10 per cent unless otherwise specified.
— all values in ohms.

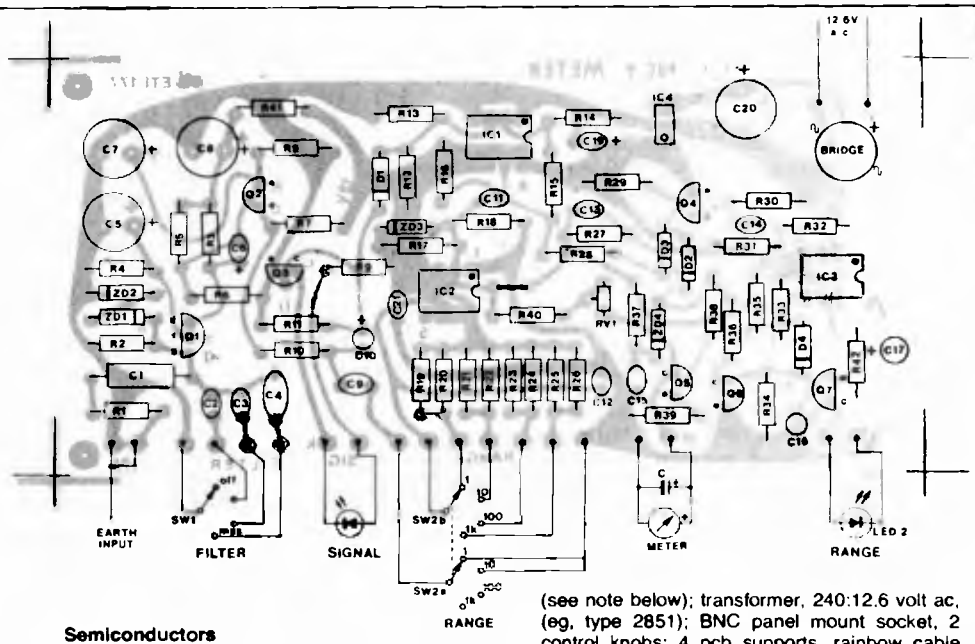
R_1, R_3, R_5, R_7, R_{27}, R_{28}, R_{31}	10k
R_2	1M
R_4, R_9, R_{13}, R_{14}, R_{16}, R_{17}, R_{42}	1k
R_6	1k2
R_8	680
R_{10}, R_{18}, R_{29}	2k2
R_{11}	3k3
R_{12}	150k
R_{15}	470k
R_{19} (with R_{20})	2M2
R_{21} to R_{26}	to calibration
R_{30}	1k5
R_{32}, R_{34}	15k
R_{33}	100k
R_{35}	4k7
R_{36}, R_{38}	68k
R_{37}	27k
R_{39}	100
R_{40}	3k9
R_{41}	470

Potentiometers

RV_1	1k miniature trimpot

Capacitors – types not specified are 25V electolytics.
– all polyesters 100V unless otherwise specified.
– all values in uF, pcb mount.

C_1	0.1 polyester, 630 volt
C_2, C_{11}, C_{13}, C_{14}	0.001 polyester
C_3	0.01 polyester
C_4, C_{21}	0.1 polyester
C_5, C_7, C_8	100
C_6	47
C_9	0.022 polyester
C_{10}	33
C_{12}	0.0015 polyester
C_{15}	1 mono
C_{16}	10
C_{17}	2.2
C_{18}	220
C_{19}	2.2 tantalum or mono
C_{20}	1000



Semiconductors

Q_1	FET type 2N5484
Q_2, Q_3, Q_5, Q_6	BC547B or similar
Q_4, Q_7	BC557 or similar
D_1-D_4	IN914 or similar
ZD_1, ZD_2	BZY88 C3V3 or similar Zener diode
ZD_3	see text
ZD_4	7.5V, 400mW Zener diode
IC_1	311 comparator, 8 pin DIL
IC_2, IC_3	uA555 timer
IC_4	uA7812, T0220 voltage regular
Bridge	W04 or equiv
LED 1-2	to suit

Switches

S_1	1 pole, 4 way wafer, or similar
S_2	2 pole, 4 way wafer, or similar

Meter Movement

1ma dc, 100 or 200 ohm coil, 80mm x 80mm panel mount (or 100mm x 80mm)

Miscellaneous

PCB or vero board; Scotchcal front panel; aluminium case, (W x D x H) 152 x 132 x 103mm (see note below); transformer, 240:12.6 volt ac, (eg, type 2851); BNC panel mount socket, 2 control knobs; 4 pcb supports, rainbow cable hook-up wire, co-ax, 240 lead and plug; grommet; terminal block; cable clamb; lugs, mounting hardware for LEDs.

Note: The case size was based on the Dick Smith case, catalogue No H-2330. However, although this unit has the same dimensions, a recent discovery shows they are for D x W x H. The larger aluminium case, No H-2335 can be used if necessary, but the front panel design will need enlarging to suit.

APROXIMATE COST = $45

ETI-177 SPECIFICATIONS
Frequency Range: 10Hz to 100kHz
Accuracy: ±5%
Minimum input voltage (sine wave): 30mV
Input impedence: 1M ohm

HI-FI SPEAKERS

This is a no-expense-spared, high quality speaker project. It uses the best components available on the market. The result is a speaker that costs less than $2000, but will give you performance better than that of a $10,000 speaker.

Mike Henriksen

Mike Henriksen is the managing director of Scan Audio.

OVER THE PAST two years we have seen an increase in the number of well designed loudspeakers on the market. However, with the fall of the dollar, they are becoming more and more expensive, to the extent that a decent speaker is now a luxury item. For this reason we decided to try our hand at designing a hi-fidelity loudspeaker.

The idea was that the speaker should use the best possible components and have the best possible performance, but at a realistic cost. We recognized that the cost would not be insignificant, but at least it wouldn't be outrageous.

The aim was to design a speaker that could compete with some of the most expensive fully imported speakers available on the Australian market.

The first question to be answered was: what drivers? Many are good, but we held the view that overall the best of the lot were those from Dynaudio in Denmark. If Denmark seems like an odd choice of country, read the accompanying specifications.

Drivers

The woofer chosen for this system is an 8" model 21W54. The basket is heavy-duty diecast magnesium with a 125 mm magnet fitted to the back. The voice coil is a 54 mm aluminium former with Dynaudio's hexagonal shaped aluminium voice coil wire. The peak linear excursion is 7 mm and a massive 29 mm maximum excursion ensures that this driver is capable of generating the lowest deep bass in a correctly tuned cabinet even at high volume.

The surround is a foam surround fitted to Dynaudio's PHA (phase homogeneous area) diaphragm, which is a polymer based mixture enriched with metal oxide particle for higher damping.

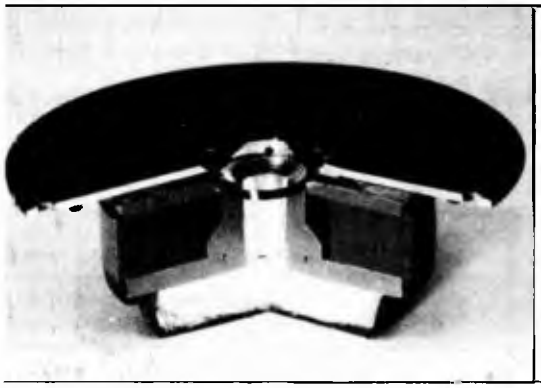
This woofer has a total Q factor of 0.303 and a VAS of only 60 litres making it ideal for a medium sized bass reflex cabinet.

We used a complicated computer program to optimize the bass reflex cabinet for this woofer. After modelling on the computer for a few hours we found that a box volume of 55 litres and a port tuned to 37 Hz would give a flat frequency response down to 40 Hz and a 3 dB down-point of 35 Hz; at 30 Hz it would be down only 6 dB.

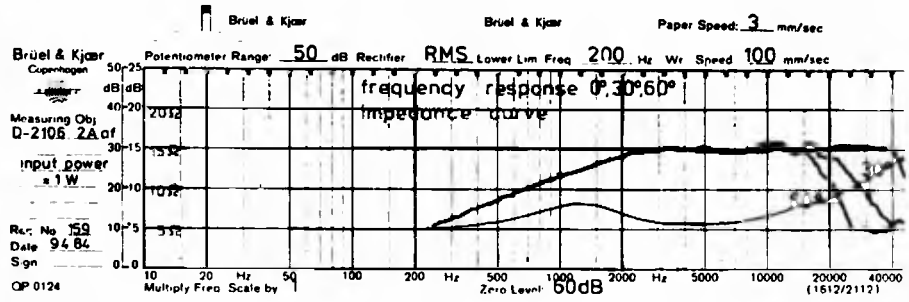
As midrange we chose the 52 mm soft textile dome midrange from Dynaudio, the D52AF.

This midrange is a very interesting construction as the voice coil is working in a ferro-fluid cooled air gap, ensuring the highest possible power handling capacity and excellent damping qualities of the diaphragm. A hole has been drilled in the pole piece making access to a rear chamber behind the magnet which is damped with long fibre wool. In this way the free air resonance has been lowered considerably to only 350 Hz, making this driver ideal for a 3-way system with low crossover frequency point. The frequency response is almost ruler flat between 700 and 7000 Hz and its dispersion characteristics are down only 3 dB at 60° off axis at 5000 Hz.

An ideal tweeter for this 3-way system was the D21AF Dynaudio Super Tweeter. Its construction is very similar to the D52 with aluminium wire voice coil with a hexagonal shaped aluminium wire, double chamber cabinet with low free air resonance and superb dispersion characteristics

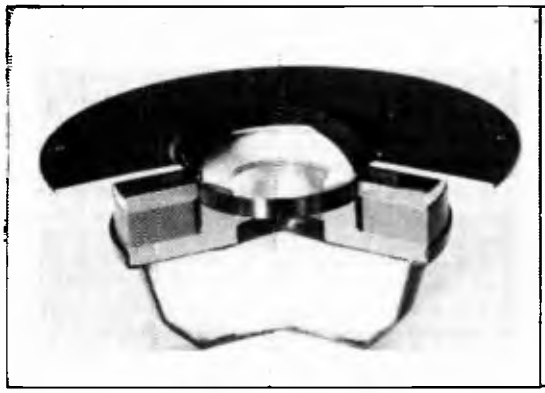


Cross section of the tweeter.

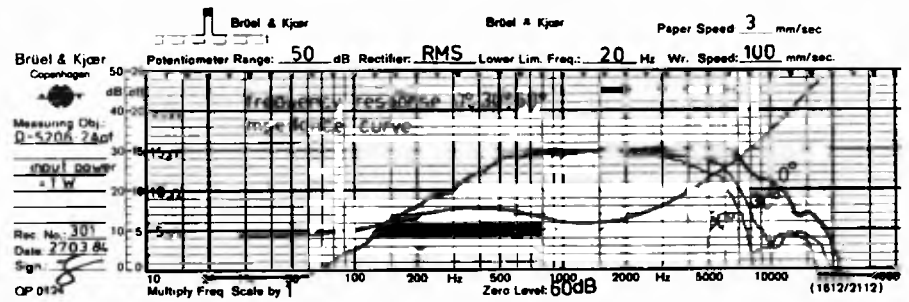


Frequency response from 3.000 up to 40.000 Hz ± 1 dB!! The impedance curve shows the resonance well damped.

D-21 AF

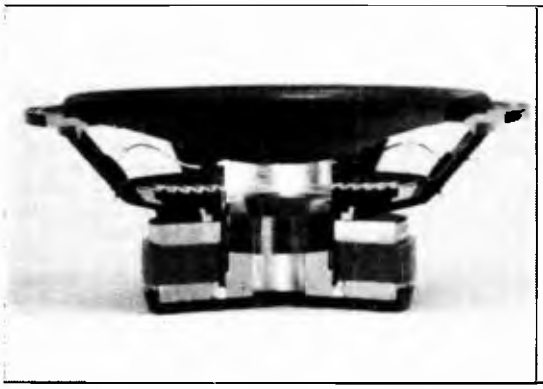


Cross section of the midrange diver.

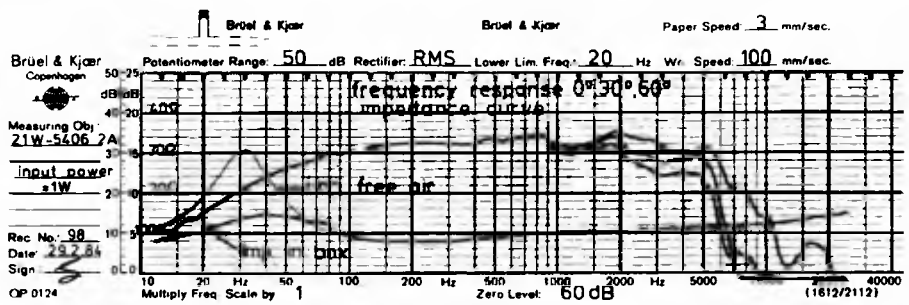


The curve indicates wide dispersion and smooth dropping at both ends which is the correct behaviour of a midrange.

D-52 AF



Cross section of the woofer.



Balanced response up to 4 kHz, important in 2way combinations. Early roll-off and high but narrow resonance impedance indicate high magnetic damping and energy.

21W-54

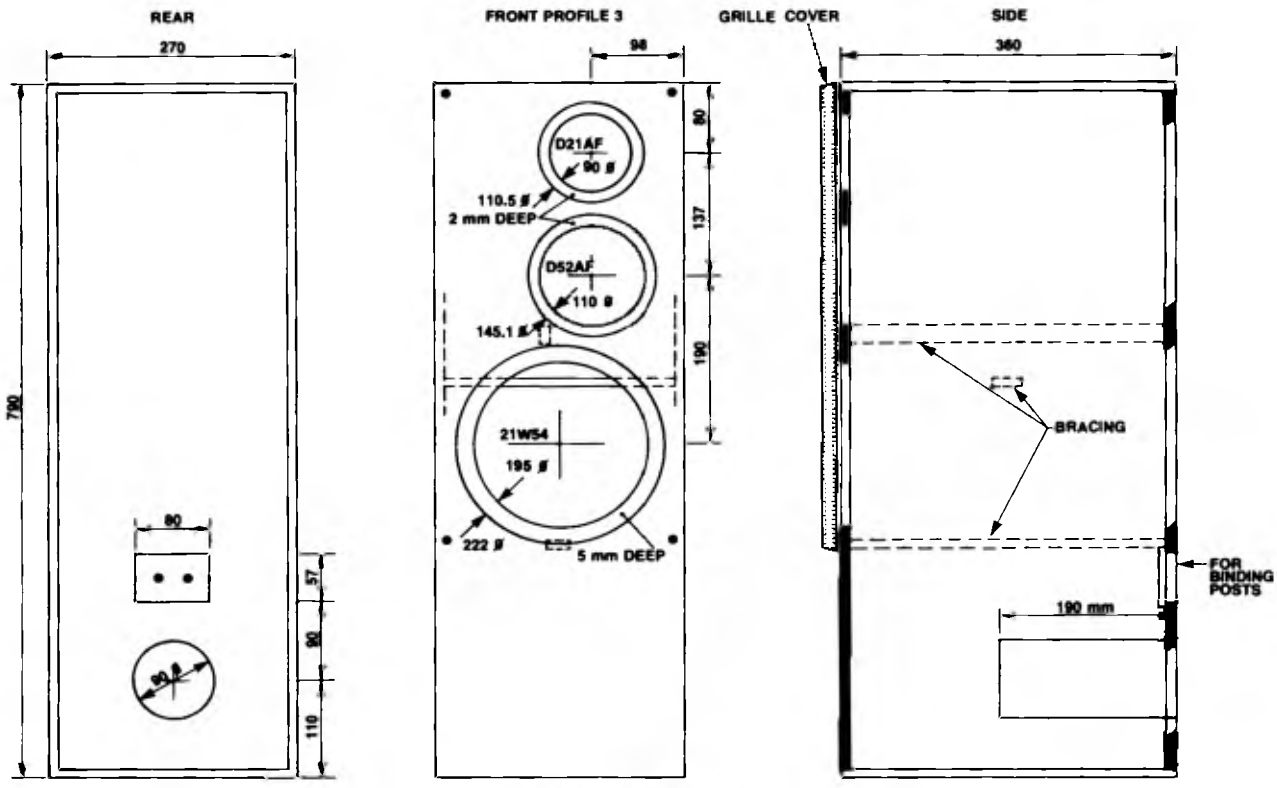
(see frequency response chart). The response of this tweeter is flat from 3000 to 40,000 Hz, its only variation ± 1 dB.

The cabinets

In designing the cabinet we aimed for a tall slim floor-standing cabinet for various reasons. By making the cabinet as slim as possible the beaming effect from the front panel would be as small as possible, and another advantage would be that the speaker would look smaller in a domestic situation.

By off-centering the tweeter and midrange we would achieve better stereo imaging because the physical distance would be different from the two edges of the cabinet. We made the cabinet fairly high, so that the tweeter and midrange would be as close to ear level as possible when the listener is postioned in an ordinary lounge chair, which we considered would be the most common listening position.

As mentioned earlier, the system was designed as a bass reflex cabinet and we had various options in positioning the port. We decided to position the port in ▶



Construction details.

DANISH LOUDSPEAKER HISTORY

Since the very early days Denmark has played an important role in loudspeaker technology and electro-acoustical engineering. As far back as 1820 the Danish physicist Hans Christian Oersted discovered the electro-magnetism, the basis for a loudspeaker. It is for this reason that the unit of magnetic field strength has got the name Oersted.

In 1918 it was two Danes, Axel Petersen and Arnold Poulsen, who were the co-founders of Ortofon, which invented the first synchronized sound to a movie.

The first primitive loudspeakers were constructed by American Edison and German Siemens, but in 1923 it was again a Dane who designed the first electro-static loudspeaker. His name was K. Rahbek.

It wasn't until 1925 that the first moving coil dynamic loudspeaker was designed. Again a Dane by the name of P. L. Jensen, the founder of Jensen loudspeakers in America, played an important role in this respect. It is this basic design that is still used in most loudspeakers today, but with some brands perfecting it to a level which makes it possible to design loudspeakers with an almost identical sound quality to the original sound. One of these companies is Danish Dynaudio.

the rear of the cabinet for three reasons. One, we would have minimal high frequency radiation out through the port towards the listener. Two, we would have one less hole in the front panel which would mean a weakening of the front baffle; and three, by positioning the port in the rear, it is easy to adjust the bass output by positioning the speaker closer or further from the wall.

We have braced the cabinet on two points from front to rear to stiffen the front baffle after it has been weakened by the hole cuts. Another brace between the two side walls has also been provided.

The crossover

As seen from the frequency response curves the three drivers have an extremely smooth roll-off in both ends. We are therefore able to use the ultimate crossover slope which is 6 dB per octave.

The 6 dB per octave crossover will give us a linear amplitude, a linear phase response, and good impulse or transient response. Crossover frquency was decided at 700 Hz and 5000 Hz.

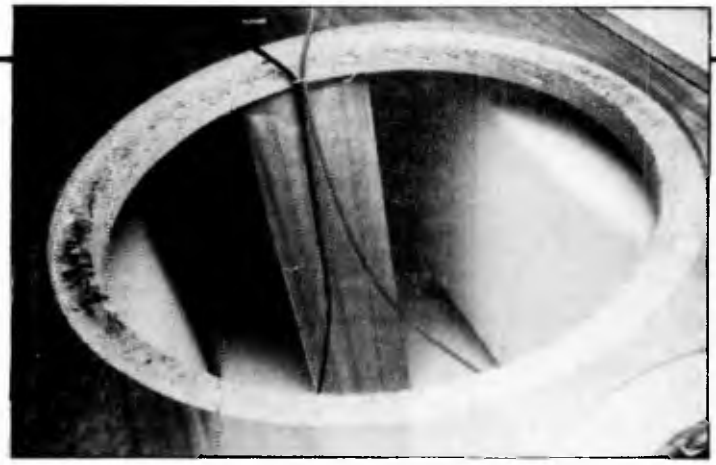
The components used in the crossover network have been chosen with no compromise in mind. The drivers are among the finest ever manufactured and it would be absolutely wrong to try to cut any corners.

The two coils for the bass driver and the midrange are low impedance, high quality air coils of thick copper wire. The inductors used are metallized polypropylene capacitors manufactured by Rifa in Melbourne. As a by-pass shunt capacitor in parallel with the metallized polypropylene capacitors are two small 10mF polystyrene capacitors for ultimate speed in the highest frequencies. An attenuation for the tweeter and midrange was necessary and here a number of non-inductive resistors have been put in parallel, causing no audible deterioration of the sound.

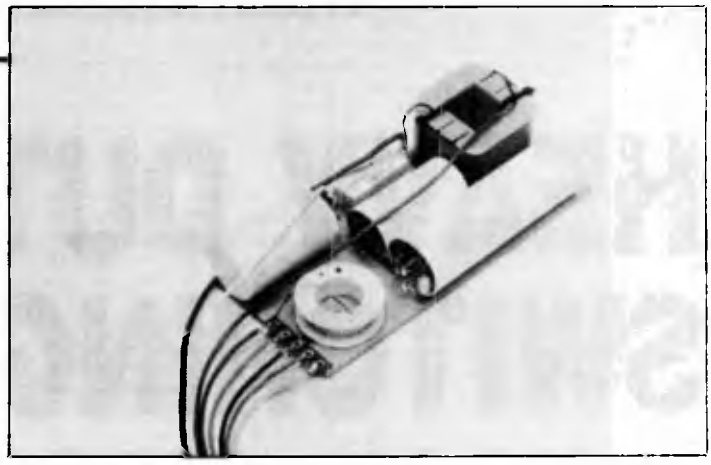
The wires that have been used to con-

BUYING

To find out where to obtain these speakers, and see them demonstrated, contact Scan Audio on (03)429-2199. The full bit will be available for $2400, but you can buy the components separately if required. The D21 costs $188, the DS2Af costs $288 and the 21WS4 is worth $378. The crossover is available for $182.



Looking down at the bottom brace.



The crossover network.

nect the input terminals to the crossover and from the crossover to the drivers are 516-strand pure copper cable manufactured by Multi-Contact in Switzerland. These have extremely low resistance and are designed for internal wiring.

At the rear of the cabinet are the input terminals which are banana sockets for the best possible connection.

Construction

Construction is quite straightforward. For the cabinet, use 18 mm high density chipboard, preferably with a genuine timber veneer. Follow the cutting diagram included here, noting the position of the bracing, which is most definititely not optional.

The speakers themselves should be rebated into the front panel. This is to achieve maximum dispersion and to minimize edge dispersion. Apart from the audio qualities, this will also increase the aesthetic appeal of the job.

Before you insert the front panel, remember to include the damping. This should consist of one inch at least of medium density foam on the rear panel and on the floor. On the side panel only take it half way to the top. This will eliminate standing waves in the cabinet and back radiation of the higher frequencies onto the woofer diaphragm.

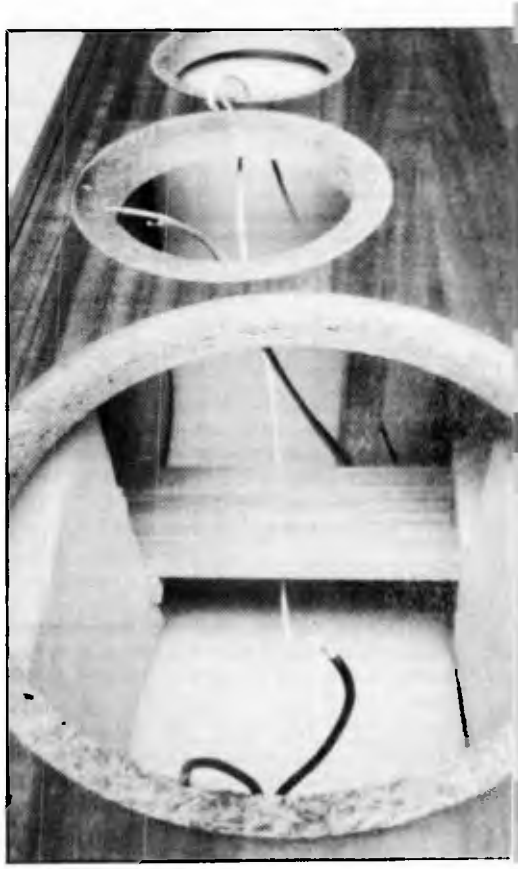
Performance

The ETI-1408 speakers are every bit as good as the performance graphs would indicate. It's clear that computer simulation of the box size resulted in a close to optimum result in terms of matching woofer against box size.

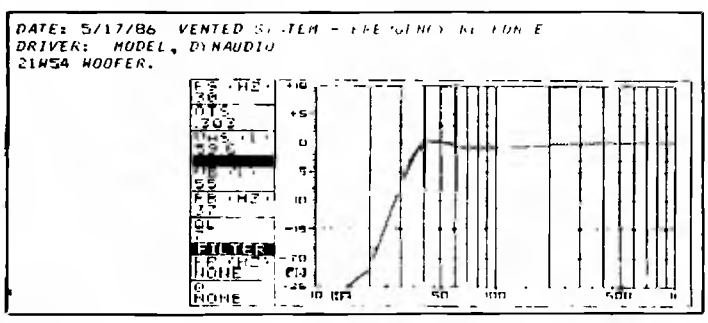
In fact, the response is particularly good right across the range. The midrange is obviously working well, but the most spectacular part of the system is the D21 tweeter. According to Dynaudia the D21 goes out to 40,000 Hz before it hits the half power point, and it sounds like it. ●

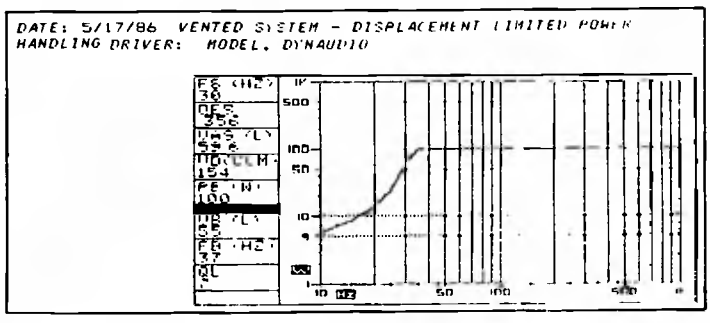
DYNAUDIO PROFILE 3 KIT SPEAKER
3-WAY FLOORSTANDING BASS REFLEX SYSTEM

Power handling:	160 Wrms (250 W peak)
Nominal impedance:	8 ohms
Sensitivity:	9 dB/1 W/1 m
Frequency response:	31-35,000 Hz ± 3 dB 24-40,000 Hz ± 8 dB (DIN 45,500)
Internal volume:	55 litres
Cabinet resonance:	37 Hz
X-over type:	1st order parallel filter
X-over frequencies:	700/5000 Hz
DRIVERS	
Woofer:	Dynaudio 21W54
Midrange:	Dynaudio D52AF
Tweeter:	Dynaudio D21AF
Dimensions:	790 x 360 x 270 mm (h x d x w)
Weight:	21 kg each



Inside the box. The crossover network is hidden by the foam at the back of the box.

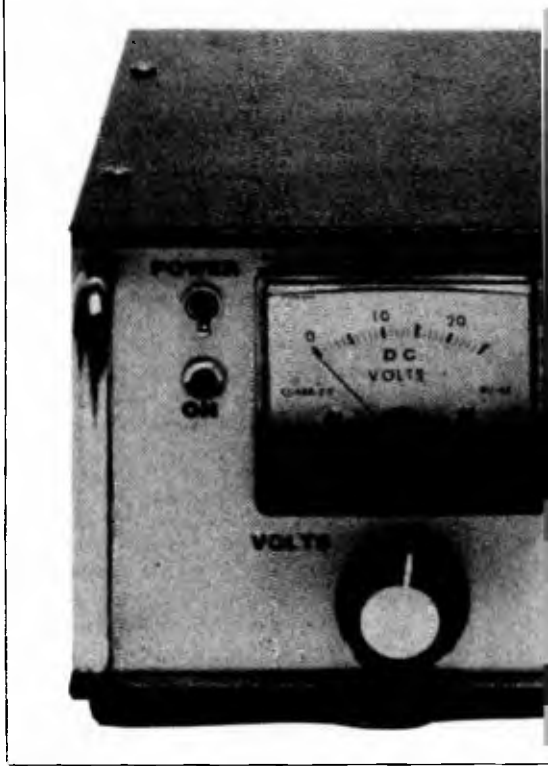




Project 1533

HEAVY DUTY SWITCHING REGULATOR

320 watts of brute power!! Another ETI maxi project that describes the construction of a 16 volt, 20 amp supply. This month the design, next month the construction.



Part 1

FOR MANY MONTHS NOW I have been annoyed by the lack of a power supply with enough grunt to deal with automotive accessories that draw a fair bit of power. Even the ETI-342 Pulse Shaped CDI Electronic Ignition drew too much power for my bog standard 2.5 amp power supply and had to be tested using a car battery. Car stereo power boosters can drawn 10 to 15 amps which is far out of the reach of laboratory power supplies. It became pretty obvious that an 'electronic car battery' would be a most useful thing to have.

I discussed the possible specifications with a few engineering friends over a beer or three. They drew my attention to the fact that a good power supply with an output capability similar to a car battery would make a perfect battery charger. No arguments and the specification became clear, an output voltage up to 16 volts and proper current limiting from 0.1 amp up to 20 amps. It could be used as a conventional power supply or, alternatively, it could be used as a battery charger and the current limit set at the maximum allowable charging rate. As soon as the battery voltage rose to 16 volts the charger would drop back to a trickle charge rate. Wonderful both ways!

A power supply capable of delivering 20 amps at 16 volts is a pretty high powered device (320 watts to be precise!) and a certain amount of care is needed when working with such power (otherwise *kablam*). The most obvious way, given current technology, is to use an off-line switching regulator. The problem with this is that you, dear reader, would have to wind your own transformer. Experience has shown that you really prefer not to and even if you did there would be a tiny chance of a mistake. Mistakes with mains voltages and powers are at best spectacular and at worst lethal so I chickened out! Given these probabilities I decided to use a commercial mains transformer to bring the input mains voltage down to a more manageable 16 Vac then rectify it to produce a 22 volt dc supply. A simple switching down-converter could then produce the regulated output.

As luck would have it Ferguson Transformers makes a battery charger transformer rated at 16 + 16 Vac out at 300 VA rating. The transformer's a bit low in output and I figured it was near enough and an awful lot cheaper than getting a special wound. The main effect of the slightly small rating would be for the supply to fade away (drop out of regulation) if the full 20 amps and 16 volts were set simultaneously. It's about the size of a brick and twice as heavy but it does fit in a readily available Horwood instrument case.

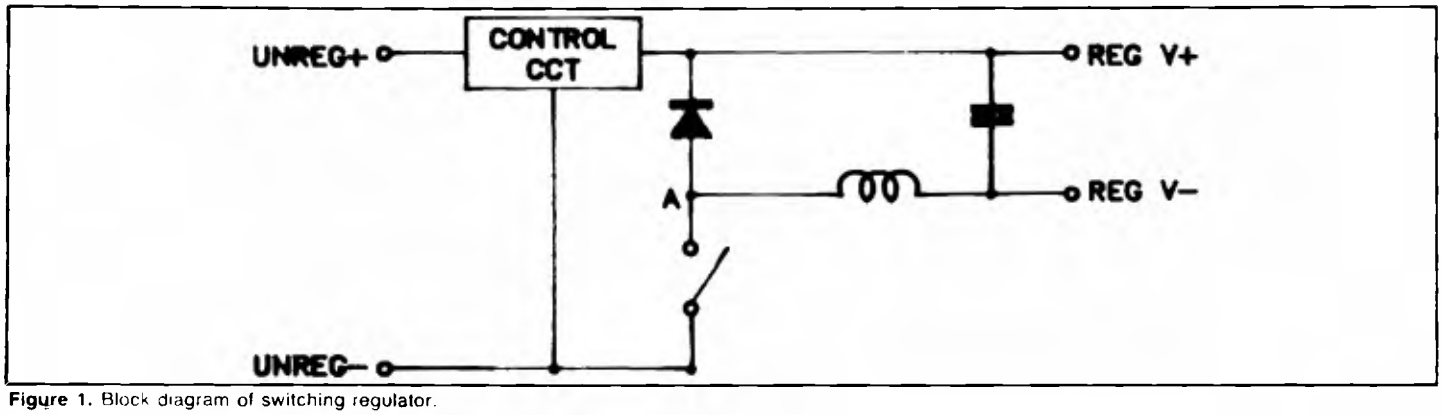
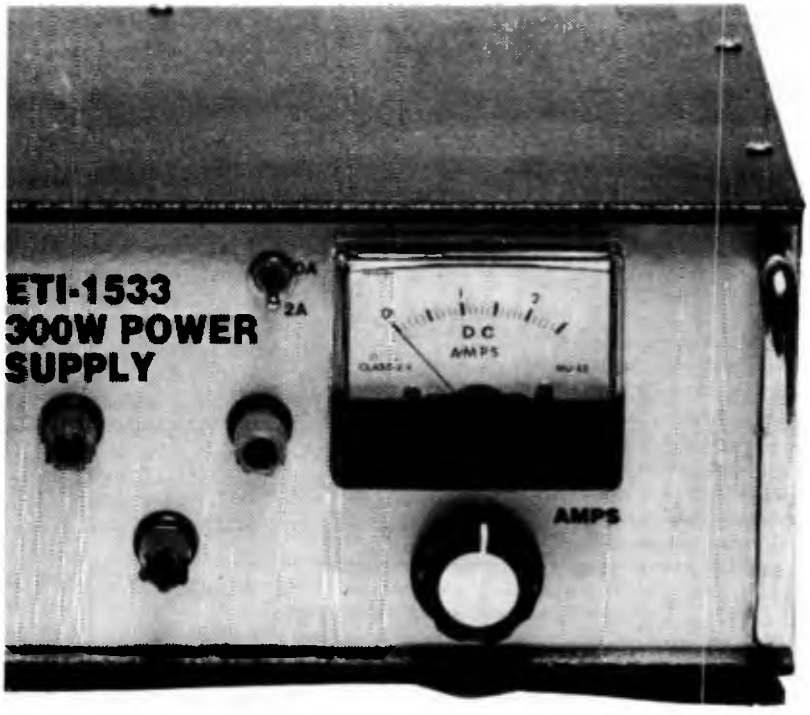


Figure 1. Block diagram of switching regulator.



Ian Thomas

Principles of operation

A switching down-converter is the simplest of all switching regulators to understand and is shown in block diagram form in Figure 1. The 16 volts ac is rectified by the bridge rectifier and filtered by the input smoothing capacitor to give an unregulated 22 volts dc supply. A series arrangement of a power FET and Schottky barrier diode are connected across the 22 volts. A series inductor is connected from the drain of the FET (and the anode of the diode) to an output filter capacitor which is connected back to the input positive supply.

The regulator uses a positive earth system as the FET is an n channel device and is easiest to operate in the negative rail. When the control circuitry turns the FET on, current is drawn from the negative output and the output filter capacitor through the inductor. Because the filter capacitors are large, the voltage across the inductor is more or less constant. This means that the current through the inductor rises linearly with time while the FET is on. When the current has risen sufficiently the FET is turned off. There is a lot of energy stored in the inductor which has to go somewhere and this shows up as the voltage on the drain of the FET going positive fast (very) and far.

When the FET drain voltage rises above the positive rail the Schottky barrier diode turns on and the inductor current is able to flow through it. During this time no power is drawn from the input supply and energy is recovered from the inductor. The current then runs down until the FET is turned on again to repeat the cycle. Control over the output voltage is achieved by varying the FET on time to off time ratio. This cycle is shown in Figure 2.

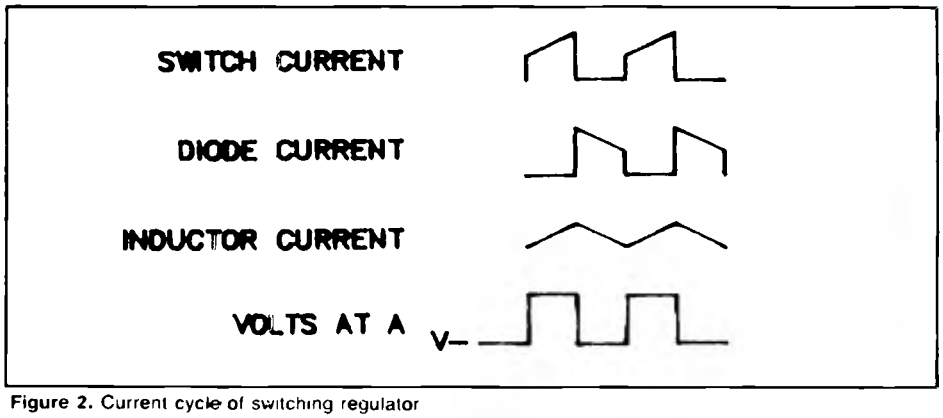


Figure 2. Current cycle of switching regulator

The reason for all this complicated switching, inductors and exotic control circuitry is in the sacred name of *efficiency*. In a conventional regulator the input diode bridge and filter capacitor are the same but the regulator that follows is not. Your average bog standard regulator is what is known as a linear regulator and in effect is an electronically controlled variable resistor between the unregulated supply and the output. The control circuitry varies the value of this resistor to ensure that the output voltage remains correct.

A quick example will illustrate what happens with a linear regulator and why it really isn't suitable. If the output was set at 10 volts and the unregulated input was 22 volts the linear regulator would have to drop 12 volts. If the regulator were supplying 20 amps then the power dissipated in it would be 12 x 20 amps or *240 watts*. This needs a heatsink as big as all outdoors and twice as bulky!

However, in the switching regulator case you will notice that the two main electronic devices that pass all the current are operated in either the 'off' state where no current is flowing or in the 'on' state where the device has almost no voltage drop across it (or as close to no volts as we are able to arrange). This results in no power dissipation (or once again as close as possible) in the devices and hence the whole regulator.

Design details

One of the first parameters that must be decided on in the design of switchers like this is the operating frequency of the whole thing. In the bad old days a 20 amp switcher would be a rather large device because the diodes and transistors that could handle the current regrettably couldn't switch from on to off or off to on very fast. In very round figures switching speed was in the order of microseconds. Today's high current power FETs and Schottky barrier diodes make things much more reasonable because they switch *fast*. Switching speeds in the order of tens of nanoseconds are not hard to achieve for FETs and speeds are almost unmeasurable for Schottky barrier diodes.

Switching speeds are very important because when a transistor switches there is a period of time during the transition from on ▶

to off (or the other way around) where the device has both a high voltage across it *and* high current through it. During this time the device dissipates power so the switching time must be made a small part of the total switching cycle. A similar type of phenomenon occurs with ordinary pn junction diodes and is known as reverse or forward recovery time. Long recovery times result in high power dissipation too.

If slower bipolar transistors are used in a regulator such as I have just described, the operating frequency is limited to 20 to 50 kHz. In the really old days when I was a spotty faced kid and transistors had just been invented, switchers used to run at audible frequencies and drive you crazy with their whistle, but I digress. This means that the inductors and filter capacitors must be *big* to deal with the lower frequencies which makes the power supply much bulkier.

Given power, FET performance switching regulators can be operated easily at 100 kHz (as this project is) and people are working with exotica at over 2 MHz. Certainly at 100 kHz everything will fit in the box very nicely.

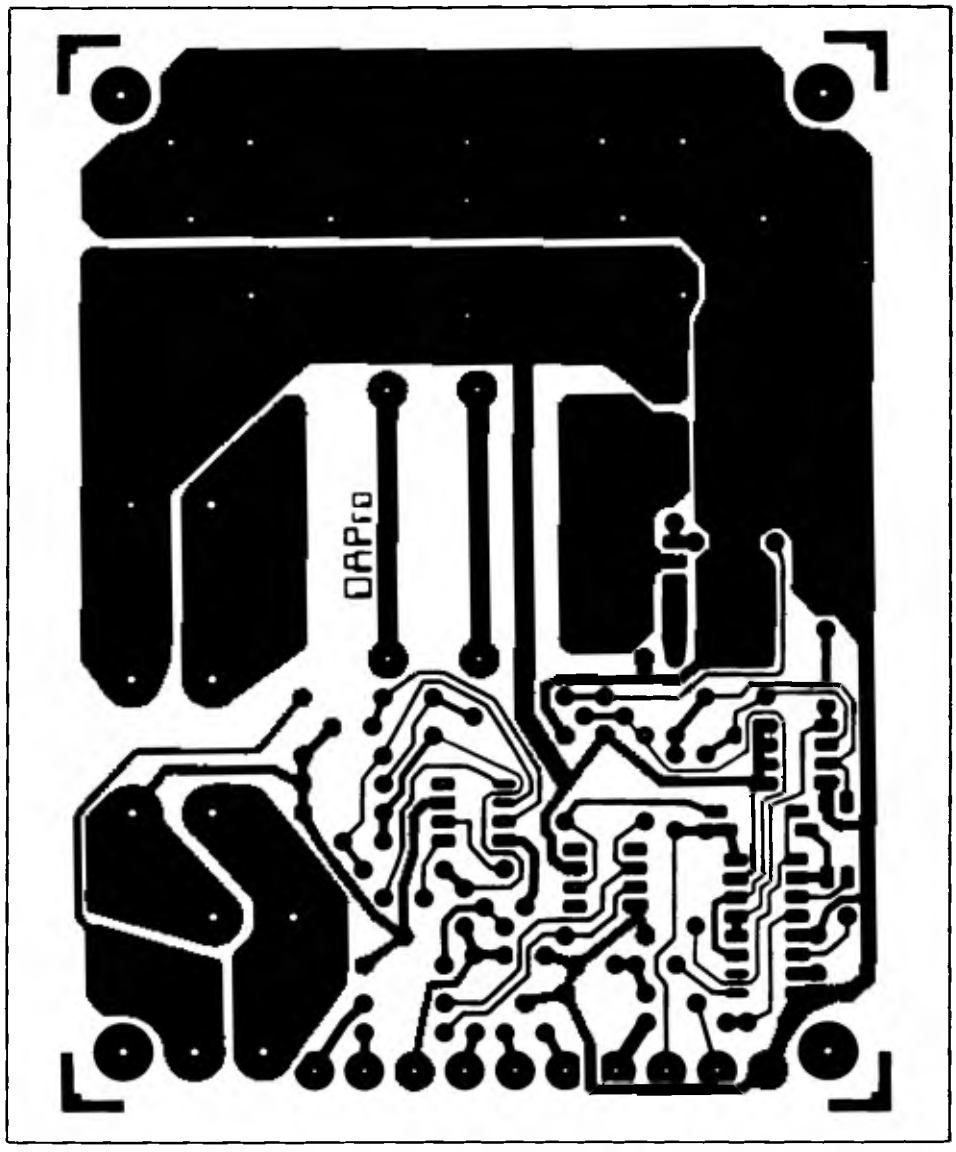
The next problem that showed up in the sums was that 20 amps is an embarrasingly large current. I could afford to put *no* resistance anywhere for any reason without the whole thing getting very hot. To illustrate this consider an ordinary printed circuit track. The ordinary one ounce copper foil on your bog standard board has a sheet resistance of approximately 0.5 milliohms/square. That is, a square of any size with perfect connections down two opposite sides will have a resistance of about 0.5 milliohms. To translate this to more understandable numbers, take a track 50 thou wide (common enough) and 1 inch long. It has effectively 20 squares of copper 50 thou on a side connected end to end. Therefore its total resistance is 20 x 0.5 or 10 milliohms. A quick bit of arithmetic shows that when the track carries 20 amps its total power dissipation is 20 x 20 x 0.01 or *4 watts*. This means the track stays in existence for a second or two at the most (poof!). The point in this is *big and short tracks* for all high current paths.

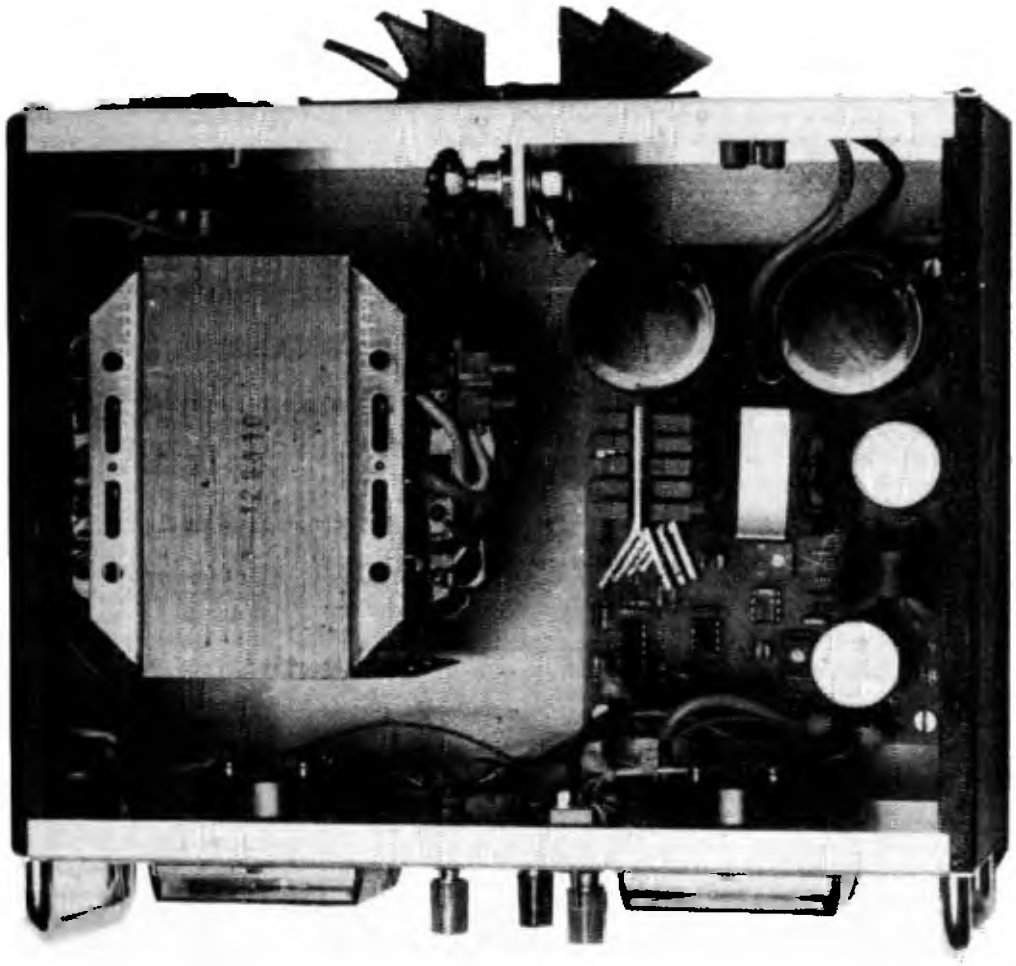
There are other problems as well. For example it is normal practice to use a small resistor in series with the output to sense the output current. Your typical el cheapo 50 microamp meter (which I used for both the voltage and current) needs to drop about 0.2 volts for full scale deflection and a shunt resistor is placed in parallel with the meter to do this. However at 20 amps the power dissipated in the current sense shunt is over 4 watts for full scale at 20 amps. The only way to avoid this problem is to use a very small current sense resistor and amplify the resultant very small voltage drop.

The main series inductor has to pass all the output current and, since it must have quite a long piece of wire to form the inductance, the piece of wire must be very thick. This is where things start to get interesting. The inductor is handling current which is being switched on and off at 100 kHz. At these frequencies electric current does not flow through the bulk of a piece of wire but tends to flow on the surface. This is known as the skin effect and for high power rf conductors copper tube is used as the inner part simply carries no current.

The higher the frequency the thinner the surface layer that carries current. If the inductor were to be wound using solid copper wire then, because the copper needs to be quite thick, the inner part of the wire would carry no current. The way to avoid wasting space in the coil like this is to not use one piece of wire but bundle several thinner strands together to form a cable (see construction details next month).

Another problem associated with high currents at high frequencies is in the filter capacitors. It would seem at first glance that a 2200 µF capacitor should have a negligible impedance. Regrettably this is not so. Aluminium electrolytic capacitors are made up of alternate layers of foil and spacer material soaked in electrolyte and rolled up. At high frequencies this rolled structure starts to behave more like an inductor than a capacitor. This is very much a function of the way the capacitor is made and the capacitor impedance varies from brand to brand so if you can't find any performance figures for the capacitor then it is better not to use it. Once again there are very high currents flowing in the output filter (not the full 20 amps but enough) and capacitors can





go bang too! The ERO brand capacitors used here are OK but others may not be so check first.

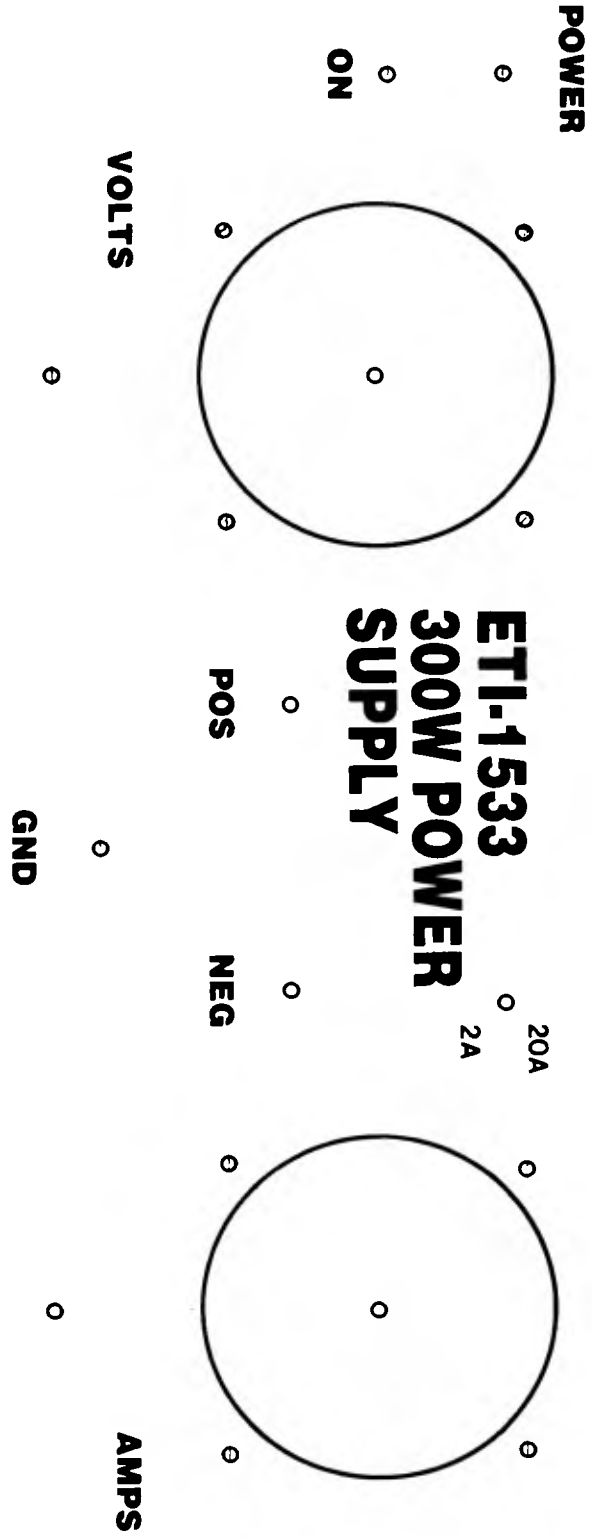
In the power supply the main switching FET and diode are mounted directly on the board. One reason is that the losses in the two devices are sufficiently low that the heatsink could be fitted on the board. This saves fiddling with wires, always a good thing to do. If the main switching devices were mounted on the rear of the unit on external heatsinks the leads to and from them would be both resistors (hot!) and inductors. The inductive effects alone could easily generate transient voltages that could break things.

When using power FETs there are rules that absolutely must never be broken. One of these is that the FET drain-source maximum voltage must *never* be exceeded. As a matter of interest I attended a seminar once on power switching where I was informed that the FET's life could be saved if the load could be shed quickly enough — say 10 nanoseconds max. Terrific! Just how that could be done the adviser didn't say. If the FET were to be wired in with long leads then an inductance of some hundreds of nanohenries would be included in series with the drain. When the full 20 amps was switched off this inductance (just 10 cm of wire!) would generate a huge voltage that would spike the FET right through its tiny silicon heart.

If you look at the layout you will see that the drain of the FET is only 2 or 3 cm from the Schottky barrier diode anode and all of the distance is solid copper. This means that as soon as a spike starts to form it turns on the diode (remember the turn on time of Schottky barrier diodes is almost immeasurably fast) and is chopped off short. This is one of the nice things about this configuration of regulator. The FET protection comes for free whereas in other types it must be separately included.

Apart from the maximum voltage rating of the FET the other parameter that must never be exceeded is the peak instantaneous current rating. The control circuitry for the regulator is an LM3524 pulse width modulator IC. This device has a lot of regrettable features but has the advantage that it is made by a lot of companies and is pretty easy to find. It has all the essentials for a switchmode voltage regulator such as a voltage reference, error amplifier and current limit sense amplifier. However the current limit amplifier has some severe limitations for FETs. The main limitation is that it is painfully slow. To stabilise the sense amplifier the designers had to incorporate a capacitor that slows the response something terrible and makes it useless as a FET overload protection device. When switching regulators are operating at 100kHz problems can occur in fractions of microseconds.

In the power supply design, that is the purpose of the LM311 comparator. A deliberately tiny amount of resistance is included in the source of the FET to sense the current through it. If this current becomes too ▶



high for any reason (the usual one being overload during start up) then the comparator output goes negative and removes the gate drive. Positive feedback is applied around the comparator so that if it is triggered by an overload then the gate drive remains off for the whole of the switching cycle. An output is available from the LM3524 that is used to reset the comparator at the beginning of the next cycle.

This solved the problem of instantaneous overcurrent but didn't help at all for steady state current sensing and constant current control. This problem was made even harder by the fact that all output voltages and current are referred to the positive rail but the LM3524 uses the unregulated negative rail as a reference ground.

Two separate operational amplifiers were finally used to sort out these problems. I've already hammered away at the fact that only small voltage drops can be tolerated if 20 amps is flowing. In this case I decided to make the drops very very small (as in a 1 milliohm resistor) and used parallelled lengths of copper wire. This makes it more of an inductor than a resistor but we can make out.

National Semiconductor makes a very nice operational amplifier in the LF355. This gizmo has two desirable features uncommon in most 741 pinout type op-amps (this is a good illustration of the point that, like oils, op-amps ain't op-amps). The first nice feature of the LF355 is its very low and stable input offset voltage. All operational amplifiers exhibit a tiny but noticeable voltage differential at their inputs which cannot be told apart from a dc input signal. Since the purpose of this op-amp is to sense just such a very small voltage then local interlopers cannot be allowed. The maximum voltage the op-amp must measure is only 20 mV which corresponds to the full 20 amps out. Fortunately the LF355 after offset adjustment to zero only has an offset voltage drift of 5 microvolts per degree C or, allowing for scaling, a total error of 5 mA per degree C in a 20 amp full scale reading.

The second nice feature of the LF355 is that the allowable common mode input voltage includes the positive rail for the amplifier. This allows the sense resistor (wires) to be placed in the positive output and avoid any possible offset movement problems (op-amp offsets often move about when the common mode input voltage is changed).

The output of the current sense amplifier is converted to a current by the transistor, Q4, and the scaling factor is set at a nice round 1 mA out of the collector, per amp of output current. The variable resistor, RV1, allows this scaling factor to be set exactly. The current sense amplifier is also used to provide some phase lead compensation to keep the power supply well behaved when in current limit. ●

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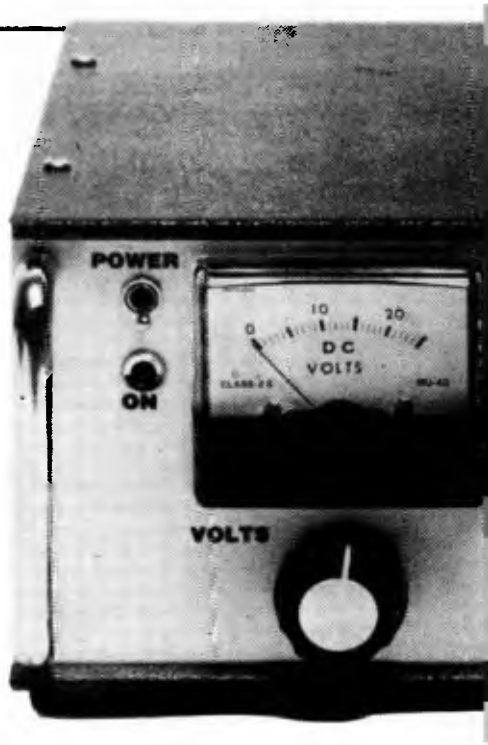
Project 1533

HEAVY DUTY SWITCHING REGULATOR



This month, the final part of our articles on a heavy duty switcher. It contains all you need to build the brute.

Ian Thomas — **Part 2**

THE CONSTRUCTION OF the power supply involves a certain amount of brute force and ignorance combined with some moderately fancy electronics. Because the power supply is capable of quite high power outputs the mechanical construction revolves around getting rid of waste power or, much better, contriving that waste power not be generated.

The mains input transformer is a Ferguson type PF4244, a damn great lump of iron and copper about the size of a brick (well — perhaps a little smaller!), and probably the greatest heat source in the whole case. This is not immediately apparent when the thing's turned on as it has a thermal time constant of a couple of hours (literally!), but it does get quite warm even when running under no load. Unfortunately this heat source is stuck inside the case where there is no ventilation.

The next great heat source is the diode bridge connected to the transformer output. This need not be stuck inside the case and, in fact, was deliberately heatsunk to the outside air, but more of this later. The rest of the regulator has only a moderate amount of heat to dissipate and so it is all mounted on the regulator board inside the case.

When assembling the power supply the first thing to attend to is the mains input, fuse and switch. This is the most important part of the power supply so far as care is concerned, as the rest of the system can do spectacular things if you make a mistake but the mains side *can kill you.* For safety reasons I chose to bring the mains into the case through an IEC mains connector. This means in practice that when you inadvertently trip over the mains cord you pull the plug out of the back of the power supply rather than pulling 10 kilos of iron down on your head (clearly a preferable option!).

The case I used is a Horwood instrument case, just the right size to accept the mains transformer, measuring approximately 255 × 205 × 100 mm. Both the top and bottom covers are just held on with sticky tape when you get it but self tapping screws are included (although not enough!!!). Remove both covers and you are ready to get serious. Cut holes in the rear of the case to fit the connector complete with screw holes, and directly under it cut another to take the fuseholder. On the top left hand side of the front panel drill a ¼" hole to take the mains switch and under it cut another to accept the power on LED.

I most vigorously recommend using a double-pole mains switch as I have *absolutely no faith whatever in the electricians switching the active in the power point.* If power comes into an instrument and then is switched on both mains lines you can turn it off and work on it in reasonable confidence that there is no possibility of meeting your ancestors. Now back to the wiring. I found it convenient to strip back the outer insulation sheath from a few feet of ordinary 7.5 amp flex for the mains wiring wire.

After the IEC connector and fuseholder are screwed in place, strip and solder a piece of *brown* lead to the pin marked A on the IEC connector. The one I purchased (from Geoff Wood Electronics. Sydney) had connector pins that were inserted after soldering which made life a lot easier. The wire could be soldered to the pin. taped safely with insulating tape and then inserted in the plastic shell. This lead should then be stripped back and soldered to one terminal of the fuseholder as it is most desirable that the fuse be in the active lead. From the other pin of the fuseholder another much longer piece of brown insulated wire may be connected and run off towards the front panel. The body of the fuseholder should be well insulated after connecting the two wires. I used a good sized piece of heat-shrink tubing I had slipped over the wires before soldering them to the fuseholder terminals.

A second lead, this time insulated *blue,* should be connected to the IEC connector pin labelled N and run off to the front panel. I neatly clamped down both leads to the side of the case in several places. As a matter of both convenience and neatness I always try to keep all wiring nicely in place. Nothing looks sloppier than a piece of electronic equipment that looks like an explosion in a spaghetti factory. To complete the wiring of the IEC connector a piece of yellow/green earth wire should be soldered to the centre pin labelled E and connected directly to the instrument case. To abide by the letter of the law you cannot use a screw that is used to hold the case together here; it should be a separate screw for the job.

The free ends of both the brown and blue wires should be connected to the centre terminals of the front panel mains switch. Extensions of the brown and blue wires should be connected to two outer terminals *on the same side* on the mains switch. Make sure that there is plenty of free space between all terminals on the switch (240 volts!) and then cover it with heat-shrink tubing. Finally terminate the two wires in a terminal block near the mains switch *in such a way that you can get to the screws when the transformer is in place.* The terminal block will serve to connect the

transformer mains side. This pretty much finishes the area where exceptional caution is needed.

With all the mains wiring out of the way it is time to start fitting all the bits and pieces into the case. Place the lower cover where it would normally go on the case and rest the transformer in position on the left hand end of the case. Make sure it clears the wiring around the rear panel but leave as much space as possible towards the front. Mark where the transformer sits, remove the bottom panel from the case and screw down the transformer. Leave all leads loose at this stage.

The next major mechanical step is the main diode bridge. I chose to keep all electronic components inside the case rather than simply mounting the diodes directly on the heatsink. This makes things a bit more complicated but allows the whole diode bridge to be made as a separate subassembly. I mounted the four diodes that make up the rectifier bridge on a piece of L-shaped aluminium extrusion, 1" x 1.5", and just shorter than the case is high The diodes are clamped to the 1.5" side and the 1" side is screwed to the rear panel. Directly opposite the bracket on the rear panel is screwed a finned heatsink which protrudes into the outside air (see photo). L-shaped extrusions are readily available at hardware stores.

If you can get them it makes life a lot neater and tidier to get two of the diodes with their polarity reversed — that is two have their anodes connected to the case and two have their cathodes connected to the case. This most assuredly makes wiring easier.

Locate just where you want the diodes to sit on the bracket by using the mica washers. The diodes should be evenly spaced along the 1.5" side of the bracket near the outer edge (so you can get to the screws that hold the bracket on). Drill four holes to accept the studs large enough to allow the insulating bushings to be inserted and deburr them thoroughly.

Each diode must be individually insulated from the aluminium bracket by the mica washers and plastic spacers that normally come with the diodes. The adjacent photograph shows just how the diodes should be mounted with the electrical mounting tag on the side away from the main diode body. At this point it is appropriate to draw your attention to the fact that high current diodes look like great big bolts but *they are not*. The bodies of the diodes are made out of copper which is as weak as yesterday's cornflakes. If you start heaving on the thread like it must carry the harbour bridge you *absolutely will* strip the thread and ruin the diode. I found the safest way to judge when it was tight enough was to watch when the spring washer provided with the diode was compressed flat.

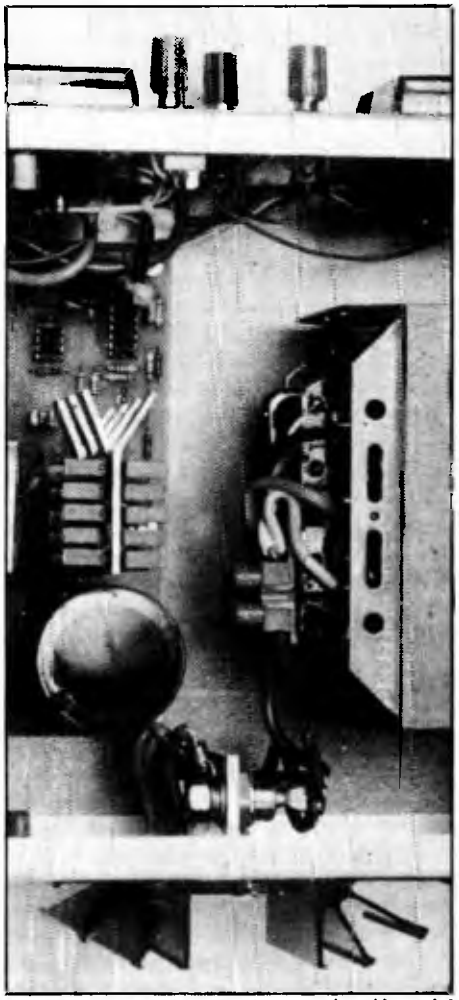
Mount the four diodes on the bracket with two of the same polarity at either end. The studs of the diodes whose case is the cathode (pointy end) become the positive terminal of the bridge. When actually mounting the diodes be sure again that there are no burrs around the edge of the holes and use heatsink grease on all mounting surfaces. Solder the two terminal lugs together and connect a 150 mm length of heavy wire (red insulated wire is nice if you have it). When wiring up the bridge and in fact the whole power supply main current paths you will have to use extra heavy duty wire. I used 7 x 0.67 mm stranded cable for all connections which seemed to do fine. Solder the terminal lugs of the other two studs whose anode (blunt end) is connected to the case and connect a piece of heavy (once again blue is nice here) 150 mm long to make the negative output.

As a matter of interest here it's always a good idea to try to observe the colour conventions as much as possible. This is because quite often someone else may go poking around inside your machine and it gives them a hint as to what is going on. This goes doubly for any mains wiring and, I think, should be done by law.

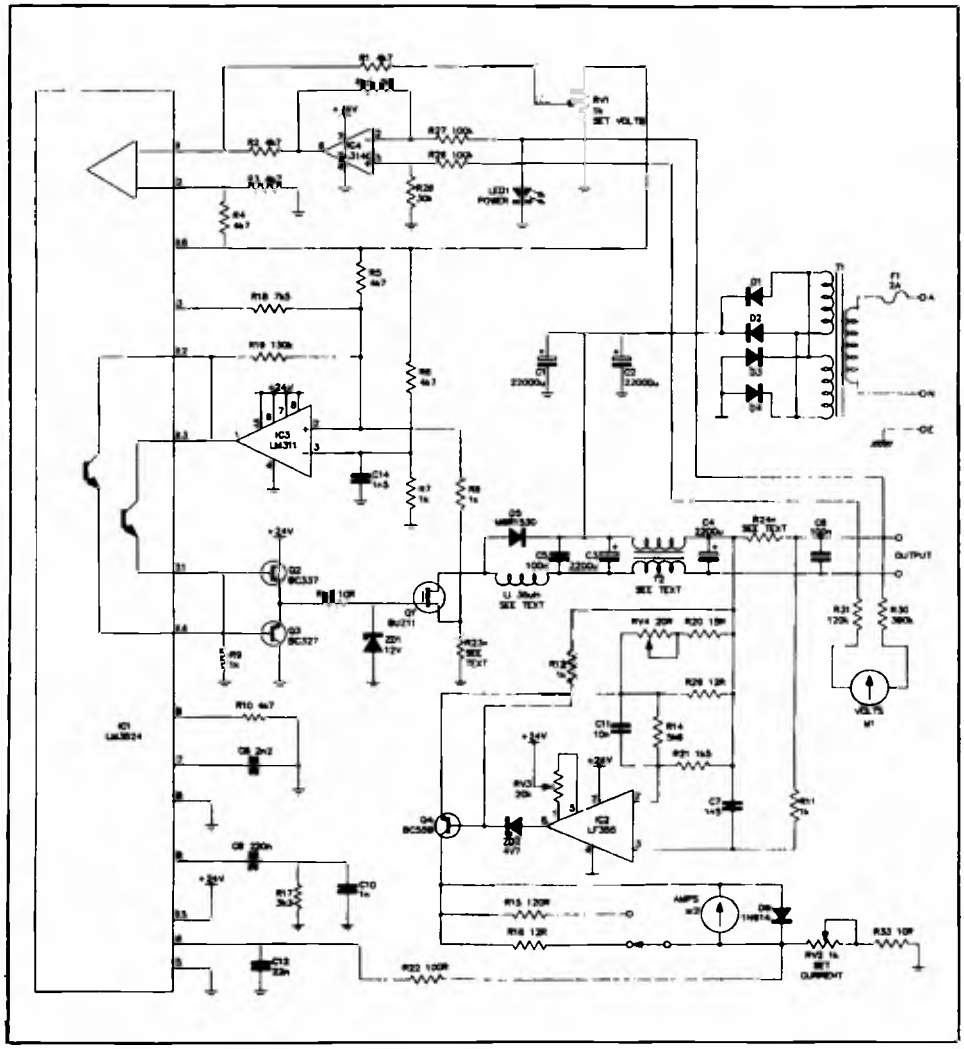
The transformer connections to the bridge are made by connecting a piece of heavy wire from one end diode around the next diode and connecting it to the third. This lead may be continued on as it connects to one lead of the transformer secondary. Repeat the process starting from the other end to make the other connection for the transformer. Both leads that go to the transformer should be at least 150 mm long. Any colour is fine here as the wiring is symmetric.

Diode wiring on the inside of the back panel.

The diode bridge can now be attached to the case. It mounts vertically in the centre of the inside of the rear panel with a heatsink mounted on the outside (see photo). The easiest way to do this is first to drill three mounting holes in the heatsink. The heatsink can then be used as a drilling template for the holes in the rear panel and bridge. 4BA screws are readily available and for these you'll need a 9/64" drill. It is also ▶



Notice the diode bridge and its associated heatsink at the top.



the right size for 3.5 mm screws for those lucky enough to get them.

Drill three or four evenly spaced holes down the centre of the heatsink mounting area and deburr them. Next hold the heatsink firmly up against the rear panel where you want it to go (*exactly in the centre*) and drill *one* end hole through the panel. Deburr the hole in the panel then position the diode bridge and mark where the hole should be. Remove the bridge and drill a hole where you've marked it.

Next screw the whole shibang together using one screw in the hole you've drilled; locate everything just right and run the drill through all the other holes *but don't bash it through the diodes — they break!* Pull everything apart and deburr all the holes. Finally smear heatsink grease on all mating surfaces and screw down the heatsink and diode bridge to the rear panel. The red and blue bridge output leads can be terminated in a 20 amp terminal block mounted on the rear panel to tidy things up. Make sure the terminal block is right at the top of the case so you can get a screwdriver in to use it! The leads from the bridge to the block should be kept as short as possible (remember 1 milliohm equals 0.4 watts!!).

The meters I chose to use were cheapie 50 microamp ones. The main problem with these was that the front panel scales were wrong. This was rectified by pulling the meters apart and removing the scales. I painted out the scale numbers and the word microamps with office whiteout. After it had thoroughly dried I filled in the correct numbers and units with a $2.50 Letraset bought from the local newsagent. The result was just a little rough looking but definitely got the message across.

The rest of the bits and pieces can now be mounted on the case. Mount the meters, control pots, output terminals and power on LED on the front panel and the case is just about ready to receive all the business parts.

The bottom of the case should first be drilled to take everything. Fit it to the case and then (flexing your mighty muscles) place the transformer where you want it to go. It should just clear the left hand side of the case and just miss all the rear panel wiring. Give yourself as much room as possible at the front as there's a bit of wiring to be done there. The leads should come out of the transformer to the sides rather than to the front and back. Mark a few holes on the case bottom from the transformer and then remove it. Next, using the printed circuit board you've made or bought or whatever, mark out the mounting holes in all four corners.

A possible problem may arise here. In the prototype I used Philips' printed circuit mounting capacitors (see Parts List). These are great devices but seem difficult to procure from component suppliers. All this means you may have trouble getting the neatsy pcb mounted capacitors I used. In this case you'll probably have a damn great lump of a capacitor to mount. The golden rule is that the capacitor must be about 40,000 or 50,000 microfarads and 25 volt-rated. Mounting it on the board isn't necessary, just nice and easy

ETI-1533—HOW IT WORKS

The power supply is a simple switching down-converter. It uses a conventional transformer TR1 to give isolation from mains and step down the 240 volts ac to 16 volts ac. The transformer output voltage is then rectified by a high current diode bridge D1-D4. The power is then filtered by the two eletrolytic capacitors C1 and C2 to give an unregulated dc output of 22 volts dc.

In order to regulate this voltage down to the desired output voltage without excessive losses, a power MOSFET, Q1, is used as a switch which is either on with a very low resistance or off and is switched between these two states at about 100 kHz. When Q1 is on current is allowed to flow from the negative unregulated rail through Q1 and L1 into the output filter capacitors, C3 and C4. The current rises linearly with time and is proportional to the voltage across the inductor. If the process were allowed to continue indefinitely eventually the output capacitors would charge up to the unregulated mains voltage, but it is not.

After a few microseconds the control circuitry turns Q1 off again. A certain amount of current is flowing through L1 which represents energy that must be recovered. The drain voltage of Q1 rises extremely rapidly when Q1 turns off and forces the high power diode D5 to turn on. The current that was flowing through the FET and inductor now flows through the diode and inductor. Because the voltage across the inductor is now of the opposite polarity, the current decreases with time. The control circuitry will continue to turn Q1 on and off in such a way as to preserve the desired output voltage and current.

For very low output voltages the transistor will only be on for a very short time and most of the output current will flow through the diode. For high output powers the transistor will be on for a much longer part of the overall duty cycle and will draw more power from the unregulated negative rail. Thus the down-converter draws just as much power from the unregulated supply as is needed and none is wasted.

The gate of the power MOSFET Q1 'looks like' a very large capacitor and in order to switch it quickly very high current must be supplied. However, this current must only be supplied during the actual switching time and when the transistor is either on or off no power is needed. Thus the two TO92 transistors, Q2 and Q3, are sufficient to provide the necessary drive current. R13 and diode ZD1 ensure that the maximum gate voltage for the FET is never exceeded.

Under normal operating conditions the main control IC, IC1, generates a pulse width modulated control signal out of pins 11 and 14. These are, in effect, two emitter follower output transistors that can be used to drive a balanced output or paralleled up as here to drive a single ended converter. The collectors of these two transistors are normally connected to the positive rail. However, for control purposes they may be used to remove gate drive if desired as is done in this circuit. R10 and C8 set the frequency of oscillation of the whole system independent of other effects.

High power MOSFETs cannot tolerate extreme overcurrents for very long. This can cause a problem as during power up the inductor current (and hence the FET current) can rise to rather high values. To avoid possible damage to the FET, the current flowing through it is sensed by the resistor R8 and comparator IC3. When the current rises too much the comparator output goes hard negative from its normal positive state and removes the drive from the FET gate. Positive feedback is provided around the comparator by resistor R19 to hold the FET off until the switching cycle is complete. At the end of the cycle IC1, the control IC, delivers a pulse out of pin 3 to reset the comparator.

The control IC, an LM2524, refers all voltages to its negative rail which creates problems as the power supply output is from the unregulated positive input to an artificially generated voltage out below the positive rail. IC4 solves this problem by monitoring the output voltage of the whole power supply and generating a dc control voltage referred to the negative rail of between 0 and 5 volts dc for a 0 to 16 volt power supply output. The voltage control pot RV1 has the control IC's reference imposed across it and adjusting the pot generates a voltage of between 0 and the reference 5 volts.

These two voltages are summed together by resistors R1 and R2 and applied to one input of the error amplifier on the control IC. The control integrated circuit amplifier generates a dc control voltage which appears on pin 9 from this control amplifier on the IC whose inputs are pins 1 and 2. The reference +5 volts from the control IC is applied to the other input of the error amplifier through two resistors R3 and R4 (this is necessary as the common mode input on the error amp is very restricted). The whole control loop always adjusts the output voltage so the voltage on pin 1 is equal to the voltage on pin 2 and, hence, the output voltage is controlled by the voltage control pot.

A second control loop is necessary to control the power supply output current. Six small pieces of copper wire are in series with the positive output of the power supply and form a current sense resistor. IC2 is a low offset op-amp which in combination with Q4 and the sense resistor form a constant current generator whose output is proportional to the power supply output current. Resistors R14, R21 and C11 form a phase lead network to compensate for the very poor frequency response of the current limit input on the control IC.

Pins 4 and 5 of the control IC are the current limit inputs. When pin 4 is taken 0.2 volts positive with respect to pin 4 (ground) the regulator starts to shut down. Thus if a variable resistor is placed in series with the collector of Q4 and the output of the power supply loaded then only enough current can flow to produce a 0.2 volt from across the variable resistor before the power supply current limits. This forms a second control loop which is only able to act when the power supply output is sufficiently loaded.

If you do have a different sort of capacitor then your board will be smaller and both should fit in OK. Locate everything on the case bottom and drill all the necessary holes. The transformer can then be permanently screwed to the case bottom and the case bottom screwed onto the case. Wire the transformer 240 volt input into the mains connector near the switch, trimming leads as necessary.

The transformer has two secondary windings that may be used in parallel (as now) or in series. The parallel connection allows much higher current at the cost of an extra diode drop in the rectified dc out. Before paralleling the windings it's a good idea to find out which wire is which (my transformer came with absolutely no information whatever), otherwise you may connect them in parallel-opposed. There are two windings so find one end of each with a continuity checker. If there's no continuity then they're separate windings. Clip the ends together and turn the beast on. Measure the ac voltage between the unconnected ends. If it's 36 volts or so the windings are parallel-opposed and you must reverse one winding. If there's almost no volts then the connection's correct.

Trim the transformer windings off with about 50 mm free and bare back the ends for 15 mm or so. You'll have to scrape off the enamel as it is a special high temperature type that can't be taken off with a soldering iron. Twist the ends you want to parallel (I checked them again to be sure) and solder about 10 mm. Insert the twisted ends into a 10 amp connector and connect up the free ends of the leads from the diode bridge to the other end. It was my original intention to stick the connector down somewhere but I found that the leads were so stiff it was totally unnecessary and the connector could just be left where convenient. Now I know why power leads like this are called busbars — they're bars you can hang a bus off! You now have unfiltered 24 volts dc at 15 amps rated.

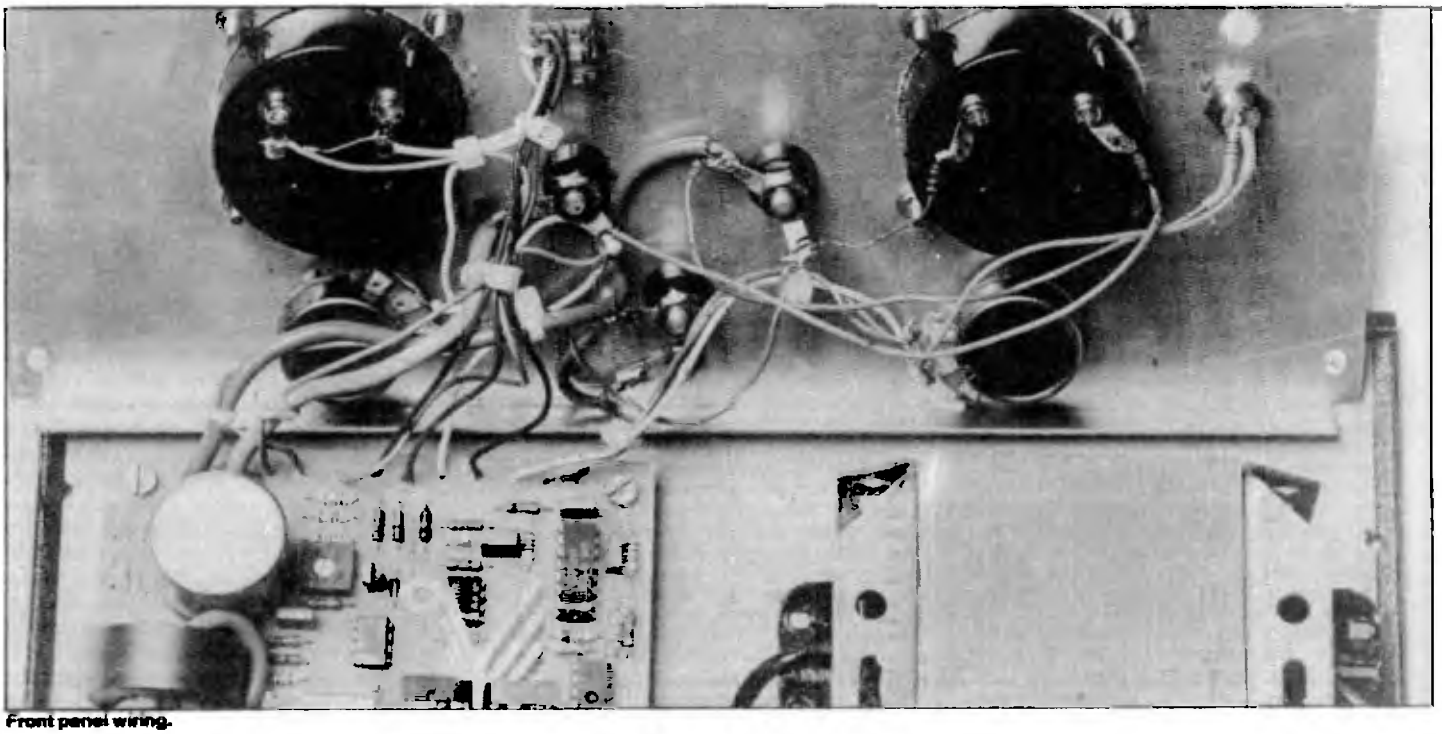
For now this completes the brute force and ignorance side of things. The next part is to assemble the printed circuit board and control circuitry.

pcb and control circuitry

The only problem here is that old one of high currents. For your information pcb laminate comes with varying grades or thicknesses of copper foil. My prototype used material with a heavier 2 oz copper. If you can get some so much the better. If you can't then things will get just the teensiest bit hotter in the case when the power supply's running full bore.

If you can't get the pcb-mounting filter capacitors then the end of the board with all the copper can be deleted. If you can then fine and make the board exactly as shown. There are several components on the main board that have to be made. The first and most important is the main inductor. The core for this is a TDK type PQ 35-35 inverter core. The coil has to carry *all* the output current so a lot of copper is needed. Most of the current is dc but there is still a considerable component of ac so I chose to make up my own stranded cable.

I used seven strands of 0.8 mm enamelled wire about 1.6 or 1.7 m long and twisted them together into a cable. The actual length needed is only about 1.4 m but you'll have ragged ends that need to be trimmed. Twisting the wire together really takes several people as the wire displays an extraordinary perversity to tangle up. The method I used was to firmly twist the start ▶



Front panel wiring.

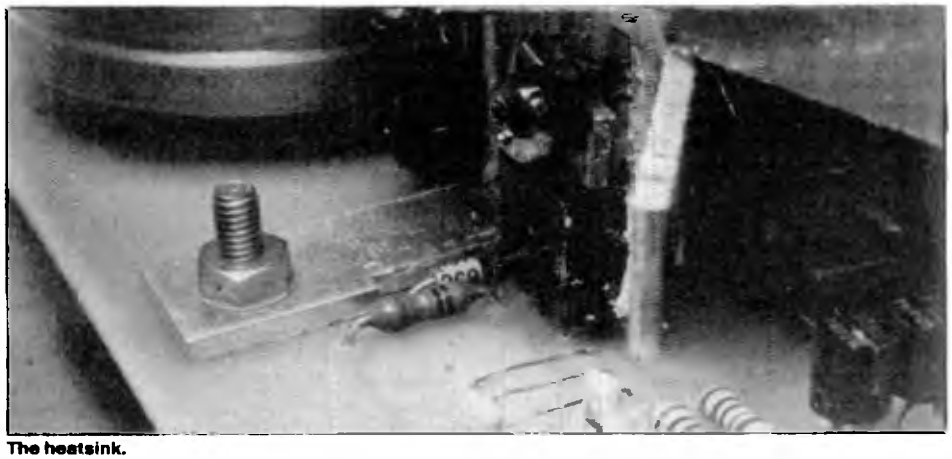
of all seven strands together and stick them in the chuck of an 'eggbeater' drill. I then threaded the free ends of the wire through seven holes in a piece of matrix board in as near to a hexagon as possible with the seventh wire in the centre. The free ends of the wire *must* be kept taut as otherwise they twist around each other. When the drill chuck is rotated the wires are twisted together to form a cable. If the matrix board is moved back so the distance between the twisting wires and the board is kept constant a neat cable will be formed. It sounds complicated but it really works.

Once the cable's been made, it's an easy job to wind it on the former. The coil former has two rows of six pins so the seventh strand must be terminated on top of one of the others but no problems. Spread out the start of your beautiful cable (after trimming off the ratty bit where you got the knack) and tin all the ends. Solder them to all the pins on one side of the coil former then wind two layers of closely spaced turns. You should fit in 16 to 18 altogether. Terminate the end down the other side in the same manner as the beginning and the coil winding is complete.

The ferrite core would saturate if it were simply assembled around the winding. This means that (a) it would get very hot and (b) wouldn't work anyway so it must be avoided. This is done by spacing the two core halves apart with some sort of *insulating* material. Anything will do; plastic draughting film is good; good stiff cardboard is fine too but it must be 1 mm or 40 thou thick. This is not a particularly critical dimension and ±20% is fine but some spacer is absolutely necessary. Cut out pieces of the material you choose to exactly the same shape as the mating surfaces of the core halves and assemble them in place. Use the clip provided to hold the whole lot together and you're ready to place the coil in the board.

The next component to be made is the heatsink to cool the main switching FET and Schottky barrier diode. I would much have preferred to use heatsinks that were available from hobbyist suppliers but couldn't find one big enough. Also the data provided by the stores weren't exactly specific ("great for those bigger jobs" !!??? — most detailed! Really all that's needed for a heatsink is *one* number — the terminal resistance in degrees C per watt. Surely that wouldn't waste too much printing ink!!).

I used a piece of 1.6 mm aluminium cut-out to the drawing in Figure 3. After cutting, fit it to where the transistor and diode are already mounted and mark where the mounting holes come on the board from the heatsink mounting tab and on the heatsink from the semiconductors. Remove the heatsink and drill appropriate holes to mount the semiconductors, bearing in mind that the tabs must be insulated from the heatsink. Next, mark off where there is free space on the heatsink and mount three small TO220 secondary heatsinks as shown in the photo. Keep them as far to one side



The heatsink.

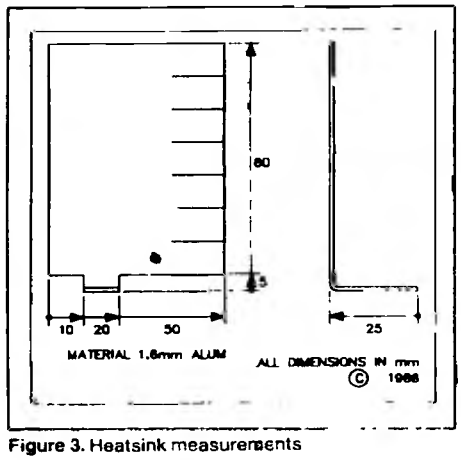
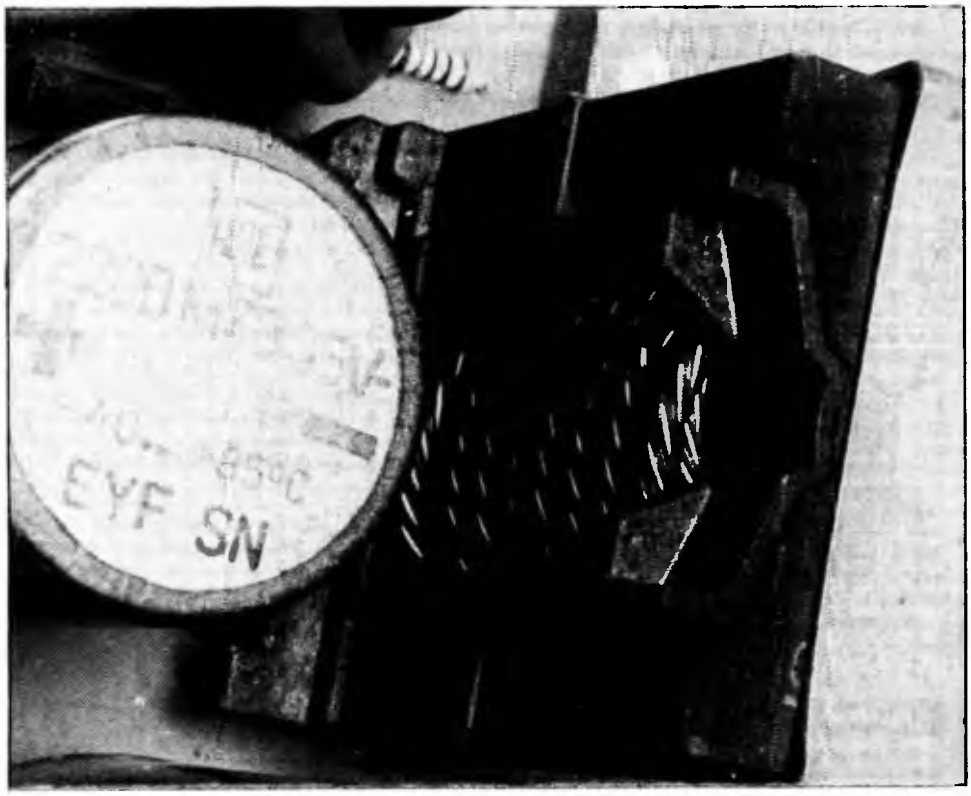


Figure 3. Heatsink measurements



The main inductor.

as possible as the free area of the heatsink has to be split with a hacksaw and bent to form fingers, once again as shown in the photo. The whole idea of heatsinks is to get heat away from the hot devices and get it into the surrounding air. To this end as many fingers as possible are good — hence all the added bits and slitting. You may wish to improvise further and it is really a case of 'more is better' so long as you can get the lid on!

After you've made the heatsink, mount it on the board and attach it with a screw through the long foot that sticks out through the diode and FET. The diode and FET can then be mounted on the board with minimum lead lengths. Both devices must be screwed to the heatsink with insulating spacers. After mounting and screwing down the power semiconductors check that the tabs are insulated from the heatsink.

The next device that has to be made is the toroidal rfi stopper. Just about any ferrite toroid will do here. It only has to be able to take six turns of the heavy duty wire used to hook up the whole power supply. If the ends of the windings can be connected directly to the holes in the board then the core is wound correctly.

The last (and easiest) components that have to be made are two current sense resistors. The first is in the source of the FET and is used to detect extreme current overloads that may arise. Here the resistance is not all that critical so I made the pieces of copper wire rather short. This means that when they get hot (as they will because they're small) their resistance will change. This is because copper shows a positive temperature coefficient of about 0.4% per degree C. It doesn't matter for the overload sense as we are only interested in *much* too much. The wire is 8.5 thou diameter or 0.216 mm and three strands are used in parallel. The wire should be cut to length and tinned before being inserted in the board or you'll lift the copper laminate trying to tin the enamalled wire in position.

The second current sense resistor is used for current limit information as well as driving the meter circuit so it needs to be more stable. The same wire is used as before but this time six strands are used to avoid getting the copper too hot. In the model only three strands of a heavier wire were used which is OK if you have reels of all sorts of wire available, but a bit of a pain if you don't.

The rest of the board is straightforward. Be sure to get the IC's in the right way round, particularly the electrolytics (they're a bit pricy). Once the board is assembled you're ready to start assembly of the whole beast. All the wires to the front panel are arranged along the front end of the board. Follow the circuit diagram carefully and connect the voltmeter through its resistors to the output terminals, the ammeter and current control pot with ammeter range change switch and resistors to the board as shown; and most importantly, the output to the feedback from the output terminals. A diode must be connected across the ammeter so that when current ranges are switched the ammeter isn't destroyed! The last thing to attend to is to wire up the power on LED complete with ballast resistor. I wired it up from available wiring on the front panel to the unregulated plus and minus rails (they're both available).

Two heavy leads should be connected to the plus and minus inputs to the board and then to the connector on the rear panel that has the outputs from the diode bridge. As a final check trace out all the wiring you've installed and make sure that it follows the circuit design exactly. Start right at the mains input socket and work through the mains switching, transformer, diode bridge and on to the pcb. Trace out all the front panel wiring insuring that the diode is across the current meter in the right direction. It may come to pass that either or both of the control pots are in the wrong way. This is fine and won't cause any harm and you can reverse it (them) when you test the unit. After all this is done the power supply is just about ready for the really exciting part — the testing.

Testing the power supply

To be quite candid this is the part I really dislike — probably because it can show up mistakes so dramatically. You actually have to plug a mains cord into the back of the thing and turn it on. The first step is to do exactly that. If the green power LED comes on then you've passed the first test. If the whole thing doesn't catch fire and burn to the ground then you've passed the second test. Now comes the serious stuff. First check that you've got about 22 to 23 volts dc on the rear panel connector that brings power to the board. Next check that the voltage regulation is working by connecting a couple of 220 ohm resistors in parallel across the output terminal. These are to ensure that the output capacitors have somewhere to discharge to when the output voltage is reduced. Now vary the voltage control pot and ensure that the output voltage does indeed vary. If it does and goes the right way (clockwise rotation increases the voltage) then at least the voltage control circuitry's working. The voltage should vary between 0 and 16 volts on the voltmeter.

At this point it's a good idea to check the voltmeter calibration. The best you can really do is check it against the very best voltmeter you can find or borrow. A 3½-digit DVM is more than enough. If there's a bad problem then you may have to change one of the resistors in series with the meter but I found that meter non-linearities ▶

far outweighed calibration errors.

The next part of the regulator circuit to check is the current sensing and current limit. First wind the output voltage down to zero and the current limit control fully anticlockwise (minimum current if you wired it correctly). There are two trimpots that must be adjusted to set the current metering. The first controls the LM355 offset and hence the output meter zero. With the output open circuit (the resistors placed across the output earlier removed), adjust RV3 until the output ammeter set on the 0-2 amp range just reads zero. You should find that for trimpot settings overly anticlockwise the current reading rises rapidly. Don't worry, it's only the reading and 10 amps isn't actually going somewhere. Set the pot so the meter is on the verge of showing something.

Next, place a short circuit across the output. This should cause no current to flow. Select the 0-2 amp range on the current range switch and slowly increase the voltage out (just a little bit is enough). About 100 mA should show on the ammeter and this is fair dinkum current. Adjusting the set current control should vary the current on the ammeter and, once again, it is the real thing coming out of the power supply terminals.

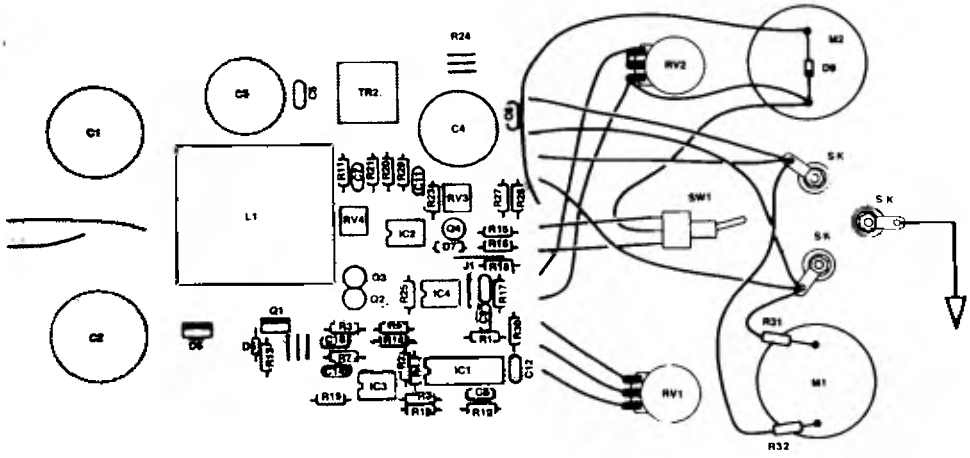
First check that you have adequate control over the 0-2 amp setting (it should take about 3/4 pot rotation to get it up to 2 amps) then switch to the 20 amp range. Slowly wind it up to full bore and make sure that nothing bizarre happens, then wind it back. It isn't calibrated yet and you don't know just how much current is really flowing. I used a piece of 7/0076 hookup wire with alligator clips on either end as the short circuit and when I wound the output up to 20 amps it got very hot!

The next step is to calibrate the current meter. What is needed is to set up a known current out of the power supply and adjust RV4 until the ammeter reads the same current. I will assume that you have a good current meter that accurately reads 2 amps (or in my case 1.999 amps). Wind both controls fully anticlockwise and then connect the ammeter across the output terminals. Adjust up the output voltage until stable current is flowing. At this point the outside ammeter in my case read about 130 mA. Next wind up the output current until the power supply ammeter reads 2 amps. Adjust RV4 until the ammeter you are calibrating against reads the same and the job is done.

It is quite possible that the range of RV4 may not be enough. This is because RV4 is adjusting for variations in the resistance of the current sense pieces of copper wire. If this is the case it may be necessary to fiddle R20 or R29 until correct calibration is achieved. Cutting, tinning and soldering in the pieces of wire results in a very uncertain resistance value.

The final step in checking out the power supply is to run it under full load and make sure nothing gets too hot. This is not as easy as it sounds as you have to get rid of an awful lot of power in the load. I made up an awful mess of steel wire on a wooden frame to approximate the full load resistance which sort of worked but tended to catch fire. A sufficient test for overheating is to run it at full current for a while and check that nothing overheats. From this point on it is probably OK to be a bit pragmatic about the whole thing and say that the current and voltage limits work fine so the whole regulator should be right.

Connect a short circuit across the output and wind the current limit up to 20 amps. Check that the heatsink carrying the power FET and diode doesn't get too hot. Hot it will certainly get but not too hot. If this is all OK then you've built a power supply.●



ETI-1533 — PARTS LIST

Resistors .....all ¼ W, 2% metal film unless noted

R1, 2, 3, 4, 5, 6, 10	4k7
R7, 8, 9, 11, 12	1k0
R13, 18	10R
R14	5k6
R15	120R
R16, 29	12R
R17	3k3
R18	7k5
R19	130k
R20	15R
R21	1k5
R22	100R
R23, 24	see text
R25, 26	30k 1%
R27, 28	100k 1%
R30	390k 1%
R31	120k 1%
RV1, 2	1k linear log front panel mounting
RV3	20k pcb mounting cermet trimpot
RV4	20R pcb mounting cermet trimpot

Capacitors

C1, 2	22m Philips Type 2222-051-46223 or equiv
C3, 4	2m2 ERO type EYF T2
C5, 6	100 n ceramic monolythic
C7, 14	1n5 ceramic plate
C8	2n2 metallized polyester
C9	220n metallized polyester
C10	1n metallized polyester
C11	10n metallized polyester
C12	22n metallized polyester

Semiconductors

IC1	LM3524
IC2	LF355N
IC3	LM311N
IC4	RCA CA3140E
Q1	BUZ 11
Q2	BC337
Q3	BC327
Q4	BC559
D1, 2	20 A 50 V cathode to stud
D3, 4	20 A 50 V anode to stud
D5	15 A 30 V Schottky barrier TO220
ZD1	18 V 0.4 W Zener
ZD2	5.6 V 0.4 W Zener
D6	1N914
LED1	green LED

Transformers

TR1	Ferguson TF4244
TR2	see text

Miscellaneous

ETI-1533 pc board; 255 x 205 x 100 mm case; 1 x SPDT; 1 x DPDT toggle switches; 2 x knobs; heatsink; 3 x banana sockets; 4 x rubber feet; 2 x 50 mA panel meters; cable ties; mains wire and hookup wire; heatshrink tubing; 4 x BA nuts and bolts; screws to fit transformer; 2 A fuse; fuseholder; Euro IEC connector; 2 x terminal lugs; 2 x 20 A terminal blocks; 1″ x 1.5″ L-shaped aluminium extrusion; Scotchcal front panel.

Price Estimate: $250

27 MHz AM transceiver

Build a hands-free operation, crystal-locked AM transceiver.
Amaze your friends by talking to them over long distances!

S. K. Hui

Part 1

IT'S BEEN almost a year since ETI has published any radio frequency (rf) projects. Finally, here comes a well designed rf circuit for you, the ETI-684 am transceiver.

The idea of this project actually came from aircraft communication. On one occasion, the editor and I were invited to have a test flight in a locally designed ultra-light aircraft. This is the first two seater ultra-light approved by the Aviation Department. Its only problem is that it's impossible for the occupants to talk to one another, even though they're sitting shoulder to shoulder. The turbulance and engine noise make it almost impossible to communicate. Just imagine how troublesome it is for an instructor to teach a deafened pupil to fly!!

The simplest solution would surely consist of a mic, amplifiers and speakers connected together by wire. But this would be all this circuit could do. Clearly, rf link would be a lot more useful. Not only would it find applications in the above situation, but in many others: walkie-talkie, links between motorcycles, cars in convoy, etc. What makes it particularly attractive is the hands-free operation of the unit, making it suitable in areas where operators are too busy to 'press-to-talk'.

Design considerations

I did a lot of thinking on the type of modulation, the carrier frequency, cost, convenience of building and legal requirements of this project. There are four frequency bands worthy of consideration. A band around 910 MHz can be used but it's rather tricky to set things up there. Very few people would have the gear to deal with a frequency this high.

There is another band at around 203 MHz used by TV and radio but operating in this band might interfere with your neighbour's favourite newly wed game program. Around 88 to 90 MHz there is an empty slot in the broadcast band, but it's (a) illegal, and (b) in Dec '85 we ran another project using it.

After a lot of soul searching, it seemed to me that a 27 MHz crystal-locked AM system would be the best compromise between ease of construction, legality, antenna length, interference and power. The band is populated by radio remote control systems as used in toys and models, and by walkie-talkies. It also requires a long antenna for efficient radiation, but in this band, an output transmitting power of less ▶

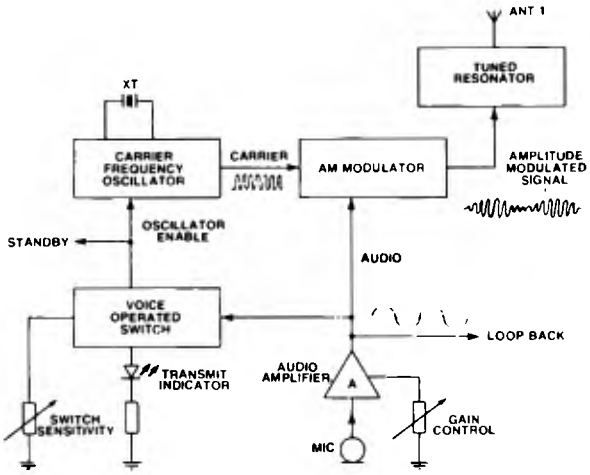


Figure 1. Block diagram of transmitter.

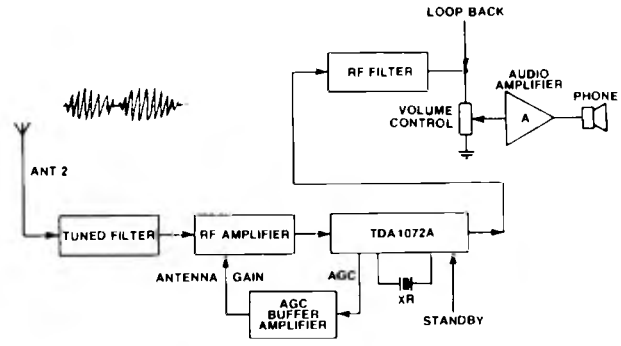


Figure 2. Block diagram of the receiver board.

than 100 mW means one does not require any licence.

It also minimizes the problems of working with high frequency design. One of the difficulties of working with radio circuits is the low gain of transistors operating at high frequencies. High loss in normal resistors becomes intolerable and tuned circuits for extracting small signal from noise need to be employed.

Circuit design

The complete unit consists of two pc boards, one containing the transmitter and the other the receiver, separated by standoffs. A battery is also included in the box. To make a viable communications system, two of the units are required. A block diagram (Figure 1) shows the essential features incorporated into the transmitter board. The receiver board is for converting the received rf into an audio signal and, therefore, as shown in Figure 2, has quite a different structure from that in Figure 1.

The transmitter board has a crystal-controlled carrier frequency generator which is enabled or disabled by the output of the voice controlled electronic switch. The reason for having this set-up will be apparent later. The amplitude of the carrier signal from the oscillator is then modulated by the audio signal in the modulator, hence the name amplitude modulation (AM). The AM signal is then further amplified by the tuned resonator before driving the antenna. An LED indicator is included which will be lit up when the unit is in transmitting mode. During standby, the unit is in receiving mode with the LED off.

Referring to Figure 2, the receiver board has a tuned filter set to 27 MHz to pick up the carrier signal. The signal is then amplified before getting to the AM

BOX MAKING

Before I committed myself to making a pc board layout, I tried to find a box of the correct size. The right sort of box has to be non-metal, low profile, reasonably cheap and common to obtain. Given the choice of boxes in the hobby shops, that left me with no alternative but to design my own custom made box tailored to the exact dimensions wanted.

The material I chose to use for the prototype was 3-ply wood. It can be obtained either from a model-making hobby shop or any timber selling place. Perspex is another material worth considering. But if you choose to follow the dimensions given here, the thickness of the 3-ply must be 4 mm. The box is built from six separate pieces labelled from A to F. The cutting dimensions of the six pieces shown in Figure 5 are all in millimetres (mm). Use Figures 5 and 6 to help you understand the next few paragraphs.

To cut a straight line on the 3-ply, the best tool is a sharp scalpel and an accurate metal ruler. Firstly, mark out the piece you want to cut on both sides of the wood. Score the wood along the marked lines with a scalpel and a ruler. Just break the wood along the cut. Cutting with a hand saw is not recommended as it leaves a rough edge to be smoothed out later.

After cutting the pieces, the next problem is to drill holes. Three of the holes (e, f and g) need to be counter sunk to account for the thickness of the wood on the sockets. Holes f and e are for the 3.5 mm phono sockets, SK1 and SK2. Hole g is for the antenna socket SK4, which is a 2.5 mm phono socket. Hole g is also countersunk to a 3.5 mm phono socket (SK3), if you want to use rechargeable batteries. Skip that hole if you are going to use normal batteries instead (see battery section). Holes j and k are for two 4BA countersink head screws.

To assemble the box, only panels from B to F are used, the lid (A) will be dealt with separately later on. The glue used was five minute quick dry Epoxy. The five pieces are glued together as shown in Figure 4. Check that the box is not tilted or twisted in any way. A right-angled ruler would help to get this right. Leave the box like that overnight to allow the epoxy to acquire its full strength. Next, smooth the box with sand paper. Use a coarse grade until the joints between panels are smooth, then finish off

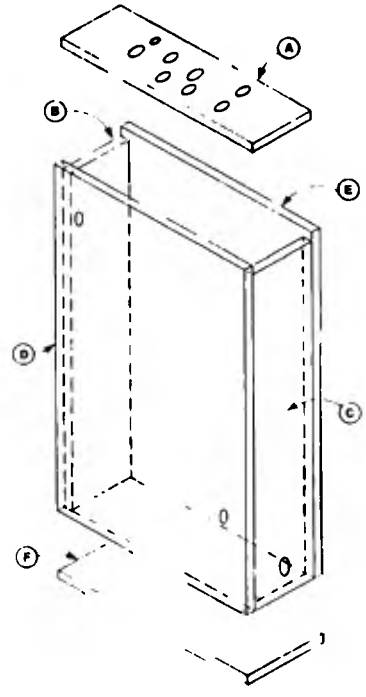


Figure 4. Assembly of the box.

with a fine grade sandpaper.

At this stage, you will probably find that the lid won't land on the box. Don't worry, this is the way it should be. Use fine sandpaper to smooth off the side edges of the lid slowly until it just fits in. Further smoothing on the top and bottom edges is required until they are level with panels B and C when sitting on the box. The whole thing sounds a little tedious here but I'm sure any handy man could do a better job than me. The motto is: If you want a good looking box, take your time!!

Next is the paint job. A single coat of matte black will suffice to protect the timber of the box. However, if you want to tart it up a bit, there is no substitute for a lot of paint. Between each coat, use wet and dry sandpaper. The result, especially when the Scotchcal panels are in place, is a very professional looking unit.

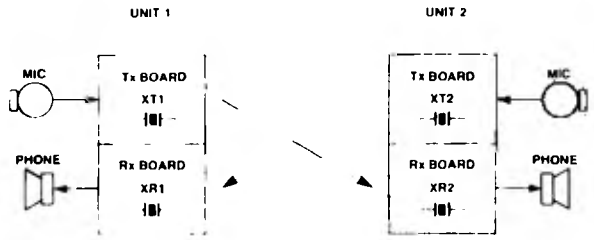


Figure 3. Complete communication system. Crystals XT1 equals XT2, XR1 equals XR2, and XT1 minus XR1 equals 455 kHz.

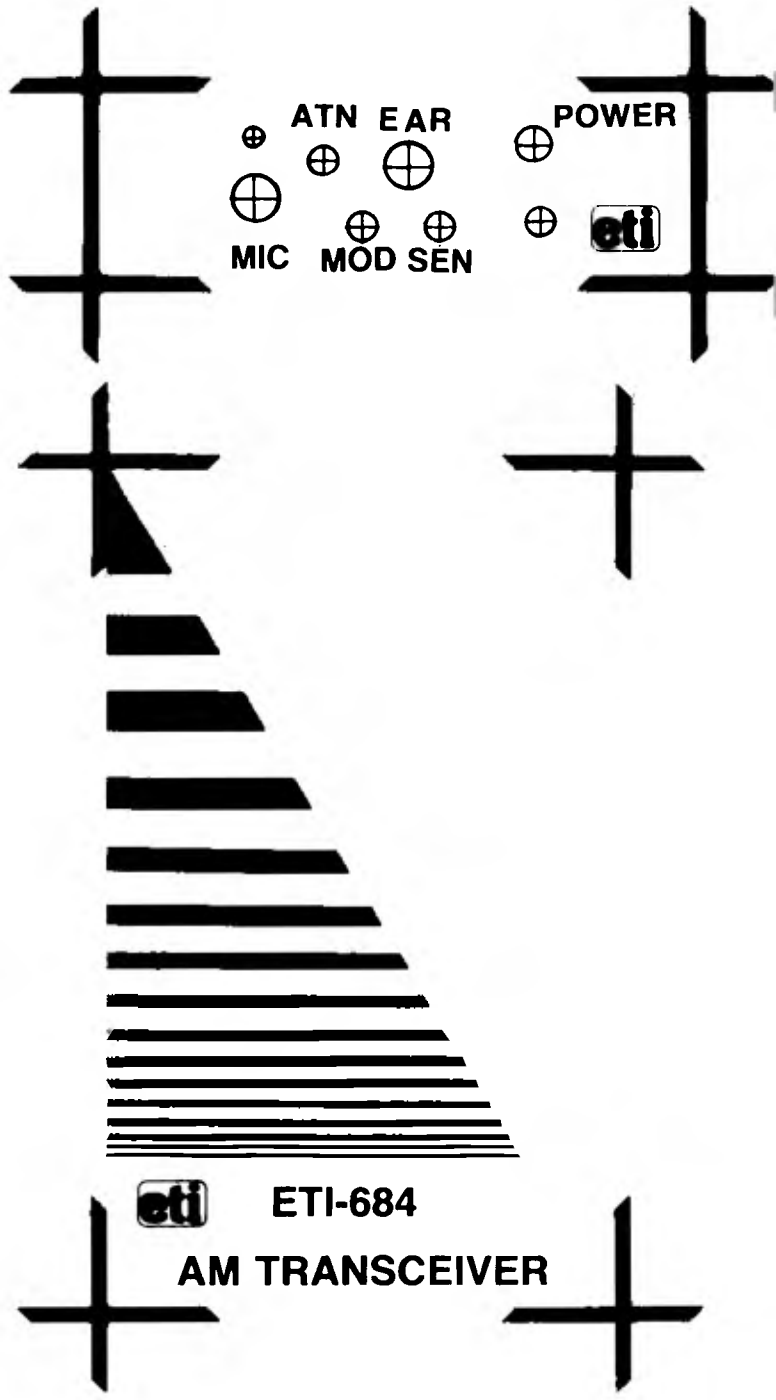
hybrid receiver chip TDA1072A (IC2), the star of the show!!! The majority of the functions done in the receiver board are controlled by this integrated circuit (IC). The IC has an internal double-balanced mixer, IF amplifier, balanced full wave detector, audio pre-amp, automatic gain control (agc) amplifier and an indicator driver. The LED indicator driver has a dc voltage output proportional to the agc signal.

The agc dc voltage is buffered and used to shut down the rf amplifier when the received signal gets too strong. The chip makers claim 1.5 μV sensitivity but in real life, I could only get 30 μV. Fortunately, the tuned rf amplifier provides a signal gain of around 12 to 30, depending on how well it is tuned so that the overall sensitivity of the receiver board varies between 2.5 and 1 μV.

The audio output from the IC is not directly usable. A simple rf filter is needed to remove any high frequency mingled in the audio signal. The purified signal is then ampified to drive the headphone.

Signals that you hear in the headphones are not only received off air during transmission, but also via 'sidetone', ie, some of the signal from the microphone is fed around to the headphone so that you can ▶

Figure 5. Cutting and drilling of the six pieces



hear yourself. It's a technique also incorporated in telephones.

Since the system is crystal-controlled, the crystals used in the transmitter and receiver have to be matched. The complete communication system shown in Figure 3 requires four crystals with XT1 equalling XT2 and XR1 equalling XR2. Furthermore, the frequency specified for XT1 (XT2) and XR1 (XR2) has to differ by 455 kHz. For example, in my prototype XT1 and XT2 are 27.165 MHz and XR1 and XR2 are 27.620 MHz. Usually they are sold in matched pairs.

Communication protocol

In any rf link, bandwidth is always the prime consideration in the design. In most cases, the less bandwidth you use in doing what you want, the better it is. That is the reason why in most walkie-talkie devices, half duplex is used. The communications channel is only wide enough to allow one way communications. Full duplex allows you to talk and listen at the same time, so, all things being equal, it requires twice the bandwidth.

The idea of having the voice-operated switch in the circuit is to eliminate the manually operated 'press-to-talk' button that is necessary in a half duplex system, giving the pilot hands-free operation on the unit. When turned on, the unit is usually in the receiving mode. If nothing is being received, all you hear is hiss.

The voice operated switch keeps the unit in this mode until the microphone picks up enough signal to toggle the electronic switch into transmit mode. It stays in this mode as long as the microphone signal persists. The switch does not toggle immediately but waits for a second or two. This is to prevent it leaving transmit mode if you happen to stop to draw breath.

Thus, the way to operate the system is to arrange for one person to talk, while the other listens. To terminate a message, some specific code should be used. The traditional 'over' is good enough. The receiver must now wait for one or two seconds before starting to speak, while the original radio is switching back into receive mode.

One word of warning: don't tune the sensitivity and the gain of the microphone amplifier up too high. It's not difficult to turn the amplifier up so high that your breathing, the wind or anything else will trigger the electronic switch. When this happens you will not be able to receive. Incidentally, one of the reasons we decided not to include a squelch system was that the background noise is the only indication the operator has that the unit is receiving. ●

ETI-746 — HOW IT WORKS

TRANSMITTER BOARD

On the transmitter board, you will find an audio microphone amplifier, electronic switch, the rf oscillator, the AM mixer and the tuned amplifier for radiation. Following the signal through the circuit, the first component we encounter is SK1. A 3.5 mm phono socket connects the microphone signal into the mic amplifier. For a single 9 V supply, the dc voltage on the output of the op-amp (JF-351) should normally be sitting at 4.5 V for maximum swing without clipping. To achieve that, pin 3 of the JF-351 should be at 4.5 V, ignoring the small amount of dc input offset voltages. This requires resistors R1 and R2 to be equal (so as to divide the 9 V to 4.5 V at pin 3). The input impedance seen by the microphone is R1 and R2 in parallel. As a rule of thumb, it should be about 10 times the impedance of the microphone. For a common 600 ohms mic, R1 and R2 are quickly worked out to be 12k each. Capacitor C1 and the combined resistance of R1 and R2 (6k) forms a low pass filter for the microphone signal. With the value chosen for C1, the cutoff frequency of the filter is around 12 Hz.

Integrated circuit IC1 forms a one stage amplifier for the mic signals. As JF-351 is a high gain bandwidth product op-amp, it is chosen to do the job. With the trimpot RV1 turned to minimum resistance, the gain of the amplifier is just:

$$1 + \frac{R4}{R3} = 821, \text{ with } R4 = 820k, R3 = 1k.$$

With RV1 turned to its full maximum resistance of 500k, total gain of 1321 can be achieved. Such a high gain is provided for situations where it may be required, but it will not always be an advantage. In high noise environments, the noise itself will trigger the voice operated switch. Capacitor C6 and R3 form the low frequency roll-off mechanism of the amplifier at around 72 Hz. The amplified microphone signal is used to trigger the voice operated electronic switch and modulate the carrier signal amplitude in the modulator.

The carrier amplitude is more or less a constant for a given battery voltage, but the audio signal is not. The louder you talk, the more microphone signal you will get. The same result could be obtained by changing the gain of the op-amp (IC1) with RV1. The larger the audio signal from the op-amp output, the more modulation will be on the carrier. Therefore, to be exact, trimpot RV1 is actually a modulation control. Hence the labelling used on the front panel for RV1 is MOD.

VOICE-OPERATED ELECTRONIC SWITCH

The electronic switch consists of three transistors Q1-Q3, resistors R5-R12, R22, capacitors C9-C11 and diode D1. Part of the audio signal from the op-amp is tapped from RV2 via C7. Transistor Q1 is biased with collector-base feedback resistor R7 forming the first stage in the electronic switch. Transistor Q1 gives a further 50 in gain and buffers the signal with its high output current to drive the timing circuit. The timing circuit is formed by C10, R9, D1, C11 and R10. The almost squared audio signal (due to the gain in Q1) appearing on the collector of Q1 is ac coupled into R9 and D1. Initially, C11 has zero voltage across it and any positive going signal appearing on R9 simply causes the diode to conduct. Capacitor C11 charges up. The negative going signal on R9 turns off the diode and stops the current from flowing back to R9 from C11. This negative going signal discharges through R9 into ground with a time constant equal to 2 (C10) (R9) = 0.3 seconds. Once the negative going signal has discharged, the cycle is ready to repeat itself. On the other hand, charge stored in C11 discharges with a much slower rate through a high resistance R10. If you keep yelling at the mic, a dc high voltage will be experienced across C1 and keep the transistor Q2 turned on.

Using the analogy of signal as water, the op-amp and Q1 are just hoses pumping water into a large bucket C10. This bucket empties itself to a smaller one, C11, which has a hole, R10, with water leaking through it.

The output of Q2 is inverted to get the right polarity and is further amplified by connecting it to a pnp transistor Q3. The extra gain from Q3 is needed to achieve an extremely fast rising voltage on the collector of Q3. Some people call this fast 'attack'. Having C10 ten times bigger than C11, so that C11 can be charged up quickly, also helps provide fast attack. As soon as you start talking into the mic, the voltage on the collector of Q3 rises quickly to V+ and causes three things to happen: LED1 lights up Q4 so as to oscillate and so provide carrier generation; the signal is carried to the receiver board via a wire link (C) to disable the receiver chip TDA1072A (IC2).

OSCILLATOR AND MODULATOR

The oscillator comprises XT, R13-R16, C12 and Q4. Normally it is in standby condition and waiting for D2 to turn on. The conducting D2 connects a high voltage V+ onto R13 and allows the circuit to oscillate. Since the oscillator is crystal-locked, the oscillation frequency will be the same as the crystal frequency. The carrier signal is coupled to the gate 1 of the dual gate MOSFET transistor Q5 for modulating and amplifying.

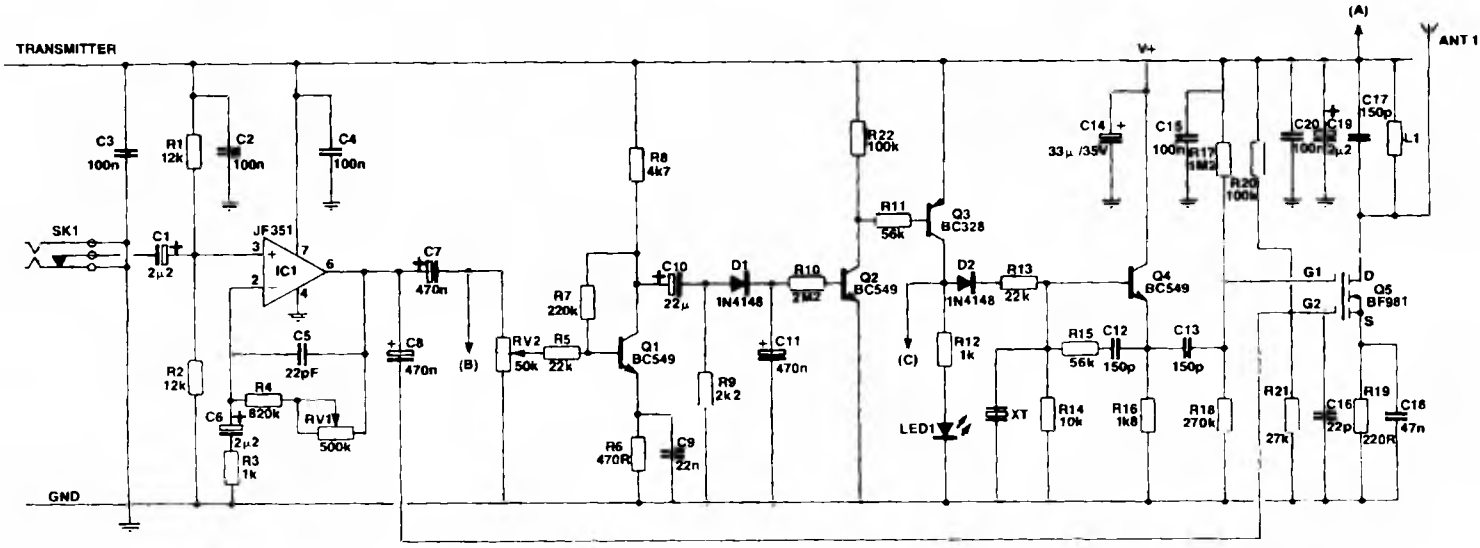
The amplitude modulation of the carrier signal is carried out at gate 2 of transistor Q5. A varying voltage on gate 2 would change the carrier signal amplitude on the drain output. This varying voltage is derived from the output of the op-amp IC1 via C8. Once again, the combined resistance of R21, R20 with C8 determines the low frequency cutoff point for the audio signal. It works out to be around 16 Hz.

RESONATOR

The resonator is formed with C17, L1 and the antenna ANT1. It is basically an LCR parallel tuned circuit which gives maximum impedance at 27.5 MHz frequency. The idea is to tune the coil L1 until maximum voltage appears on the drain of Q5.

RECEIVER BOARD

Signals picked up by antenna ANT2 are coupled to the first bandpass filter L3 and C21. A bandpass filter antenuates all other frequencies except the centre frequency which is tuned at around 27.5 MHz. Output signal from the filter is further amplified by Q6 and the second tuned resonator formed by L4 and C24. The overall gain on the sig-

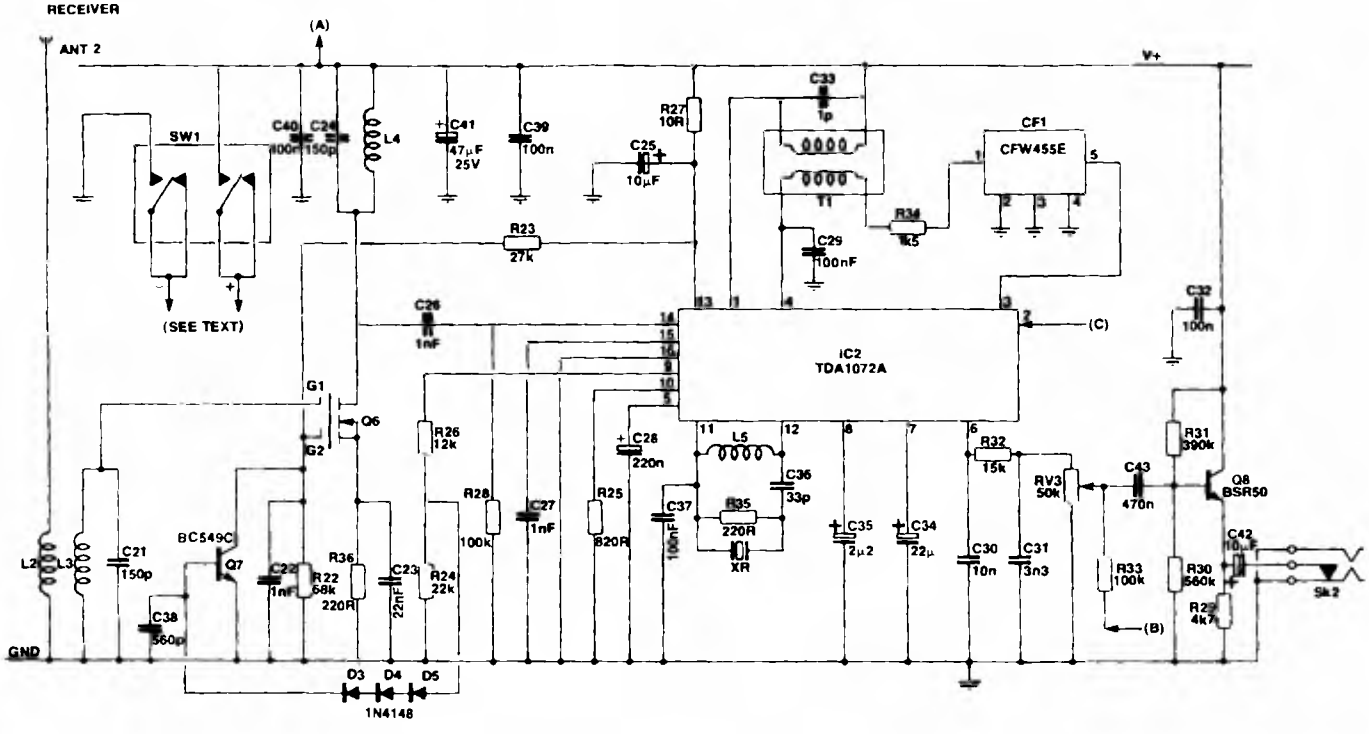


nal from the antenna input to the drain of Q6 is about 12 to 30. This is then coupled onto pin 14 of IC2 via C26.

The centre of attention in the receiver board is the TDA1072A (IC2). Inductor L5, C36, R35 and XR are the key components required by the internal oscillator in the chip. If the internal oscillator of the chip is running properly, its output signal should appear on pin 10. Pin 2 of the chip controls the standby operation of the IC. A high on this pin causes the chip to go standby and a low (0 V) enables the IC to receive. An internal double balanced mixer is used to generate the IF signal. The mixer output (pin 1) is the collector of a transistor pair which requires a positive dc voltage for biasing. Using a resistive load to supply the dc voltage would reduce the maximum IF output signal; an inductor should be used in coupling the mixer output to the IF amplifier (pins 3, 4). In the actual circuit, an rf transformer (T1) is used. The output signal from the transformer does not return to the IF amplifier immediately. The in-built high IF gain amplifier allows the IF selectivity to be provided by an external ceramic filter (CFW455E).

A buffered dc output which is a logarithmic function of the aerial input voltage over the full dynamic range is available on pin 9 for driving a field strength indicator. In the design, pin 9 is used to drive gate 2 of Q6 with the help of Q7, D3, D4 and D5. Gate 2 on transistor Q6 controls the gain of the amplifier and will shut it down in the event of receiving a strong signal. In situations where the transmitter is too close to the receiver, signal received would be strong enough to swarm the rf input stage of the IC. Some kind of feedback mechanism to shut down the rf amplifier is quite essential.

Finally, the demodulated AM signal appears on pin 6 which is connected to an internal audio preamplifier with an emitter-follower on the output stage. Such a low impedance output stage enables a low pass filter to be constructed externally, for filtering the residue rf component in the audio signal. The audio output from the low pass filter is tapped from the trimpot RV3 and mixed with signal from the output of IC1 via C7(B). They are then amplified by a Darlington transistor Q8 to drive the headphones.



27 MHz TRANSCEIVER

Part 2

This month we finish showing you how to build ETI's terribly, terrific transcendental, transceiver.

S. K. Hui

Construction Transmitter

SINCE THE CONSTRUCTION of the box was explained last time, here I will concentrate on assembling the board. First check the parts list to make sure you have the correct components. There should be two different pc boards in your kit, the transmitter and receiver boards. Start with the transmitter, since it will be needed when you test the receiver board.

Once again, you will either love or hate my way of designing the pc boards. I believe that my designs make assembling the boards easier and cheaper. I have deliberately arranged to have the tracks on the component side of the board and used the bottom side as an earthed ground plane. This arrangement provides a solid ground plane and the least number of holes on the board. This reduces the cost of the board to minimum.

On the transmitter board the first components to be assembled are the transistors. Most of them have their pins cut short and soldered directly onto the board, except the emitter of Q2, which goes through the board and is soldered in the conventional way. As a general rule, when you see a dot hanging off a pin of a component on the overlay diagram, that pin goes through the board. A blank dot sitting on top of a dot [illegible] feed through wire is needed at that point.

Be very careful to make sure none of the transistors' pins are bridged as the spacing between them gets very small after the pins are cut short. The easy one is Q5 though care must be taken to ensure the polarity is correct when being soldered. Figure 1 shows the pin arrangement of Q5 and Q6. They are dual gate MOSFETs housed in a 'button' shape SOT-103 package.

Resistors and diodes can be soldered now but don't forget that some of them have their pins through the board.

Capacitors are soldered as before except that C14 should lie flat to keep the board profile low. Be sure to study the photograph carefully and compare it with the component you are about to solder. Solder in the crystal. Be sure to keep it clear of the surrounding tracks. Integrated circuit IC1 is put on next. All pins of the IC

Specifications

SUPPLY VOLTAGE TO AM transceiver: +12V

1. Unit standby current consumption: 70 mA.
2. Frequency Response (−3d B point)
(a) Transmitter: 100 Hz-100 kHz
(b) Receiver: 100 Hz-2.5 kHz.
3. Distortion Figure: 2.6% at 1 kHz modulating frequency with 30% modulating depth.
4. Signal to noise ratio: 40 dB (at 1 kHz modulating frequency).
Conditions in which testing (3) and (4) were carried out are; Modulating signal (sine) at 1 kHz is injected into the mic socket with an amplitude to produce 30% modulation depth. The output signal to be examined is tapped out from the phone socket in the other unit. Two units are separated by 500 mm with no antennas plugged into the antenna socket (SK3). But the socket is connected to the pc boards through two pieces of wire 120mm in length each. In testing (4), the noise refers to the noise received with the modulating signal in the transmitter turned off and the carrier turned on by disabling the voice operated switch.
5. Microphone input is designed to take 600 ohm impedance microphone. Phone output will drive any standard headphone.
6. Operating range (width 9V battery).
Test Condition: One meter antennas, 9V voltage on open field, With antennas held up.
Signals start to fade out at around 550 meters.

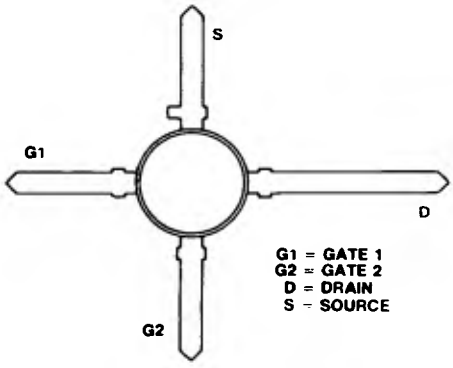


Figure 1: Pin arrangement of BF 981 (sot-103) transistor.

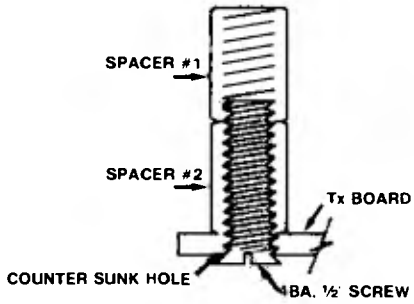


Figure 2. How to mount spacers on transmitter board.

should be cut flat except pin 4, which goes through the board.

The last few components to be mounted are the ones sitting on the front edge of the board like LED1, RV1, 2 and SK1. The way you bend the pin of LED1 or RV1, or the exact spot you solder SK1 will have to match up with the mounting holes on the front panel of the box. Notice that you still have not mounted the coil L1. Leave it for the time being and concentrate on the receiver board.

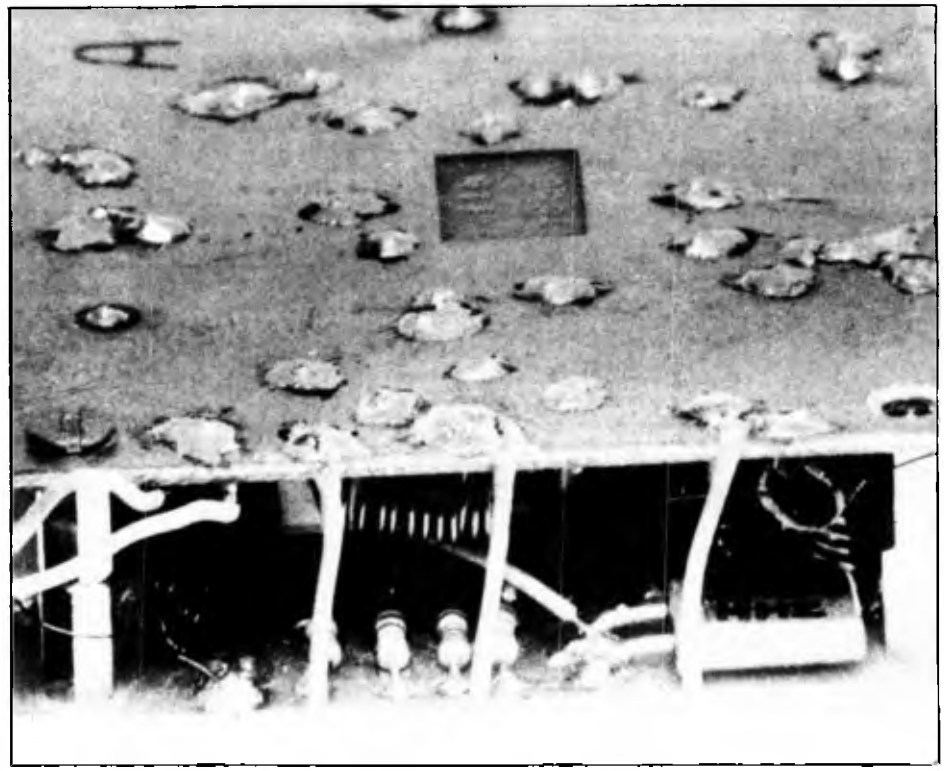
Receiver

The construction of the receiver board is similar to the transmitter board despite a few odd components. Once again, we leave the coil construction to the last. First load the transistors, then the resistors and diodes. Watch the polarity of the diodes. Before you start to solder the capacitors, you must load the ceramic filter (CFW455E) and the RF transformer T1. Their pin arrangement is shown in figure 3. Pin 2, 3, 4 of the CFW455E should be soldered on the bottom of the board. Pin 1 and 5 have to be bent about half way along their length to make a foot for soldering to. Transformer T1 has three pins on its primary side which should face toward C33. You should cut the centre pin short as it is not required when bending the other pins be careful to keep them clear of the case, and be careful of shorting the case on the surrounding tracks. The power on/off switch Sw1 is a small DPDT toggle, pc board mounting type from Dick Smith Electronics. I tried unsuccessfully to obtain the same one from other places. The switch has six pins for electrical connections and one for mechanical strengthening when mounted on board. Referring to the overlay diagram, they are labelled as P1, P2 to P7. Only pin 6 and pin 7 have to be soldered onto the other side of the board. Pin 1 to 5 should be tailored so that they are just long enough to touch the soldering pads when the switch is on the board.

Setting up the unit

At this stage we have no coils on the boards, no power and a problem. There are no reliable 27 MHz transmitters around, so we have no way of knowing when the receiver is set to preceisely 27 Mhz. Without a reliable receiver, we can't set up the transmitter. Is this the end of all our dreams? Not at all.

The first thing to do is to apply power to both boards. The battery and the on/off switch are all located on the receiver board. Check the transmitter and the receiver overlay diagrams carefully, and find the spots labelled as A, B, C. These should be joined together with thin hook up wires. Label A brings the rail from receiver to the transmitter board. ▶



Three hook up wires also serve as a protecting fence for the coils.

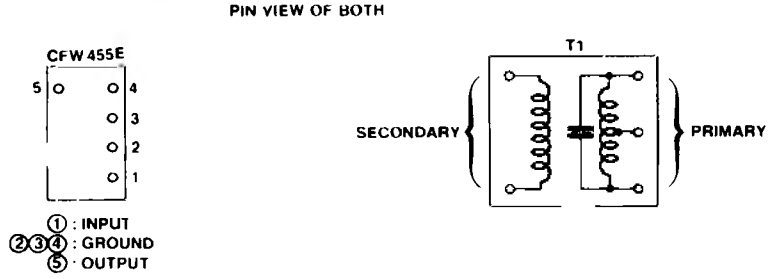


Figure 3. Pin arrangement of CFW455E and T1

Label B brings the audio output from the op-amp to the headphone driver Q8 so you can hear yourself when you transmit. Label C brings the voice operated switch output to IC2 and disables the receiving chip. Label D on the overlay diagram has no physical meaning. It merely indicates the continuation of the wire from the receiver board antenna port to the socket.

Earth Connections

There are three connections between the two boards but no earth. Although the metal standoffs can be treated as earth connections between the two boards, it is not very reliable. I decided to use dedicated wires for the job. Not only do they make a good connection, they also serve as a protective fence for coils L2, L3 against the battery when the boards are lowered into the box.

Tuning circuit

Now we are ready to begin work tuning the coil. If you look at the box on Coil Construction, you will get a good idea of how this should be done. With the coils soldered into place we are ready to start. The technique is quite simple. We have developed a small tuning circuit that, when applied to your multimeter will give you maximum output when the receiver is turned to 27 MHz.

Since the correct tuning coincides with the maximum amplitude of carrier across the coil, the trick is quite obvious: simply rectify the carrier signal and smooth it out to dc voltage so it can be measured by your multi-meter.

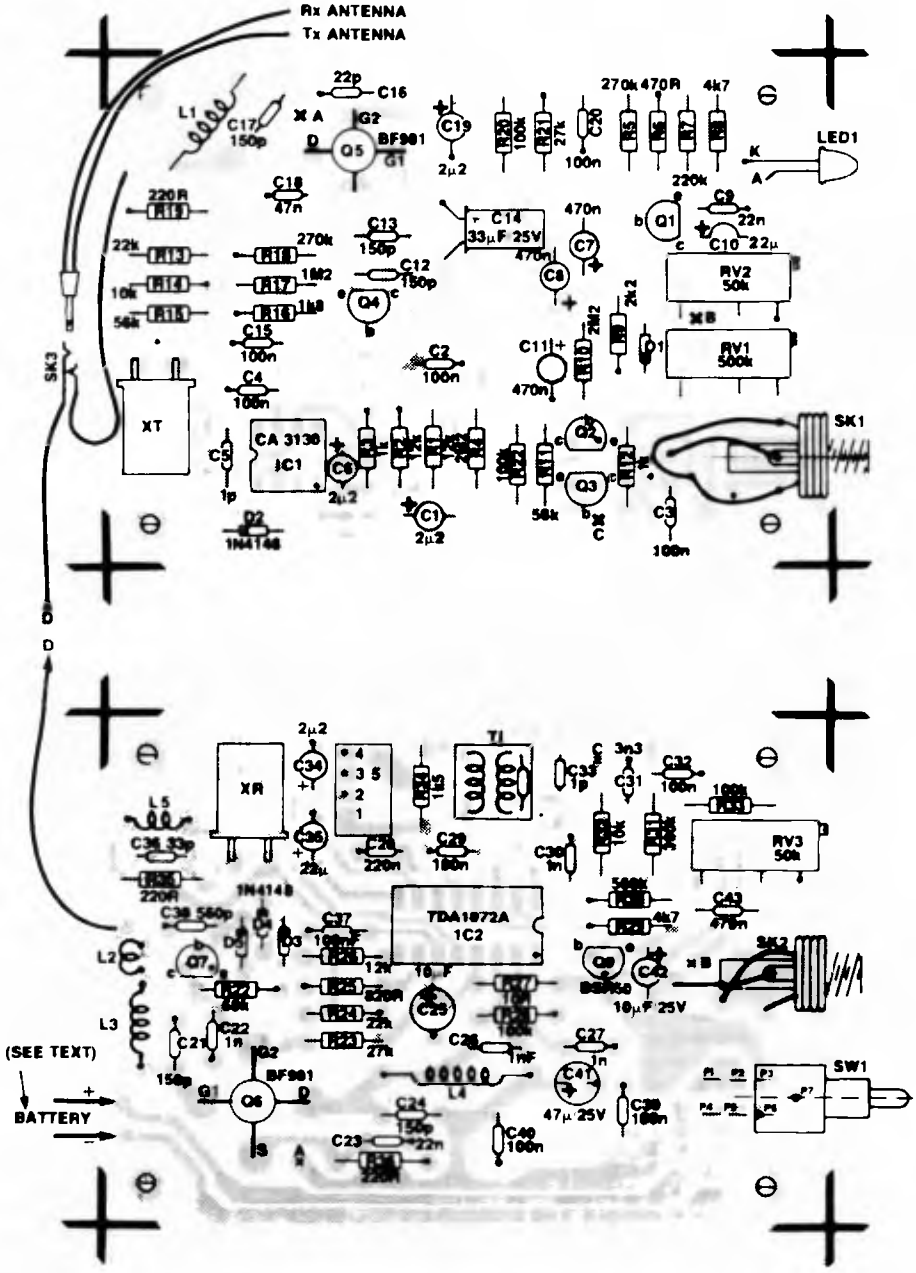
The tuning circuit is shown in figure 4. If you wish you can mount it on vero board or some equivalent. I suggest you simply birdsnest it together. It's only temporary, after all.

Tuning Procedure

The tuning mechanism is the same for all coils. However, each individual coil requires its unique tuning condition to be set up. So here they will be dealt with individually. The tools you need to tune coils include a multi-meter, the tuning circuit, a long 6 BA brass screw and a ferrite slug.

Coil L1

This is the only coil used in the transmitter board. Its function is to form a resonating circuit with the antenna and C17. To tune it properly, a unique antenna has to be selected first. There are two antennas, one for transmitting and one for receiving. The trade-off in picking the right antenna length is a long one for further operating range versus a shorter one for convenience and mobility. My suggestion is one meter long for both. The advantage



is you can check your unit against my published information since I used a one meter antenna myself during the testing.

Solder your two antennas into a 2.5mm phono jack and plug it into the SK3 socket. Bear in mind that the SK3 socket is connected to the antenna ports on the transmitter/receiver pc board via two thin insulated hook up wires. Normal hook up wire can be used for the antennas. Separate the two antennas in to a 'V' shape and maintain the shape with cello/masking tape during the tuning process.

The power required by the tuning circuit should be tapped from the transmitter board. The output from the tuning circuit should be connected to your digital multimeter with alligator clips. Otherwise, you will be too busy holding the meter probes when you tune the coil. To tune the coil, you could start off with the brass or ferrite screws. Slowly insert the screw into the coil and keep an eye on the meter output reading. The reading can decrease or increase depending on which screw you use and how far it is inserted into the coil.

Brass decreases the inductance of the coil but ferrite increases it. Similarly, the inductance of the coil will be increased if it is compressed (small pitch) and decreased if stretched (larger pitch). The whole idea is to insert the screw into the ▶

PARTS LIST — ETI-746

The parts list listed below are only for building up one unit. A complete system consists of two such units, therefore everything listed below needs to be doubled.

Transmitter board

Resistors.....(¼W, 1%)
- R19.....220R
- R6.....470R
- R3, 12.....1k
- R16.....1k8
- R9.....2k2
- R8.....4k7
- R14.....10k
- R1, 2.....12k
- R13.....22k
- R21.....27k
- R11, 15.....56k
- R20.....100k
- R7.....220k
- R18, 5.....270k
- R17.....1M2
- R10, 4.....2M2
- RV1.....500k multi-turn trim pot
- RV2.....50k multi-turn trim pot

Capacitors
- C1, 6, 19.....2µ2/16V or higher (Tant)
- C2, 3, 4, 15, 20.....100nF (disc or monolithic ceramic)*
- C5.....1pF (disc ceramic)
- C7, 8, 11.....0.47µF/16V or higher (tant)
- C9.....22nF*
- C10.....22µF/16V (tant)
- C12, 13, 17.....150pF*
- C14.....33µF/25V (Elec.)
- C16.....22pF (disc ceramic)
- C18.....47nF (disc ceramic

Semiconductors
- Q1, Q2, Q4.....BC549 or BC109 (Bipolar npn)
- Q3.....BC328 or BC558 (Bipolar pnp)
- Q5.....BF981 Philips Dual gate MOSFET
- D1, 2.....IN4148
- IC1.....CA3130E FET input op-amp
- LED1.....3mm dia. high efficient LED

Miscellaneous

One 3.5mm mono phono socket (SK1) for the microphone input. A crystal, the one used in the prototype is XT=27.620 MHz (Dick Smith Electronics part number B-9604). Eight 4BA tapped metal spacers with four counter-sink hed 4BA, ½ inch long screws. Half a meter long hook up wires and 6 inches long 22 SWG insulated copper wire for winding up coil L1.

Receiver Board

Resistors.....(¼W, 1%)
- R27.....10R
- R35, 36.....220R
- R25.....820R
- R34.....1k5
- R29.....4k7
- R32.....10k
- R26.....12k
- R24.....22k
- R23.....27k
- R22.....68k
- R28, 33.....100k
- R31.....390k
- R30.....560k
- RV3.....50k multi-turn trim pot

Capacitors
- C21, 24.....150pF*
- C22, 26, 27, 30.....1nF*
- C23.....22nF*
- C25, 42.....10µF/25V (tant) or (Elec.)
- C28.....0.22µF (tant)
- C29, 32, 37, 39, 40.....100nF (Monolithic ceramic)
- C31.....3n3 (disc ceramic)
- C33.....1pF (disc ceramic)
- C34.....2µ2/16V or higher (tant)
- C35.....22µF/16V or higher (tant)
- C36.....33pF (disc ceramic)
- C41.....47µF/25V (tant) or (Elec.)

* Philips Subminiature Plate Ceramic's. ref. Philips Data book C15.

Semiconductors
- IC2.....Philips TDA1072A AM-receiver
- D3, 4, 5.....In4148
- D6.....BF981
- Q7.....BC549 or BC109
- Q8.....Philips BSR50 (darlington)

Miscellaneous

Miniature toggle switch (SW1) from Dick Smith Electronics. A 3.5mm phono socket (SK2) for the audio output to the phone. A ceramic filter (CFW455E) from irh components. The RF transformer could be obtained from Dick Smith Electronics again, the catalogue number is L-0260. It is sold in a pack of four, the transformers are distinguishable by their colors. The one you need has a black color slug. One foot long 22 SWG insulated copper wire for winding up L2, 3, L4. Two feet long 28 SWG insulated copper wire for winding the L5 and for connecting the antenna ports from the pc board to antenna socket SK3 on the front panel. Four 4BA counter-sink head ¼ inch long scews for fixing the receiver board onto the spacers.

General Assembly parts

A 9 volt battery clip. A meter of hook up wire. If you are going to incorporate socket SK4 for battery charging or intending to operate the unit from external source, extra socket and a resistor is needed. The socket is 3.5mm phono type with a 330R, ¼ W resistor. The antenna section consits of two one meter long hook up wires and a 2.5mm phono jack. The headset I used in my prototype was from AUDIO TELEX model number 63-500/001 (the 500 series) but other series would also work so long if the mic. and phone impedance matches with the circuit specification. It is understood that the headset and the case (as described ini last issue) may not be supplied in the kit pack.

Parts for the tuning circuit

(Please refer to circuit shown in figure 4)

Resistors.....all 0.25W, 1% tolerance
- 1 X.....27k
- 1 X.....10M
- 1 X.....68k
- 1 X.....220R

Capacitors
- 1 X.....150pF*
- 1 X.....0.1µF (tant) or Monolithic ceramic
- 1 X.....47µF/25V (Elec.)
- 1 X.....1nF (disc ceramic)

Semiconductors
- 1 X.....BF981 Philips Dual gate N channle MOSFET
- 1 X.....1N4148 small signal diode

Price estimate: $100 approx. per unit (excluding the tuning circuit, the wooden box, battery and the headset)

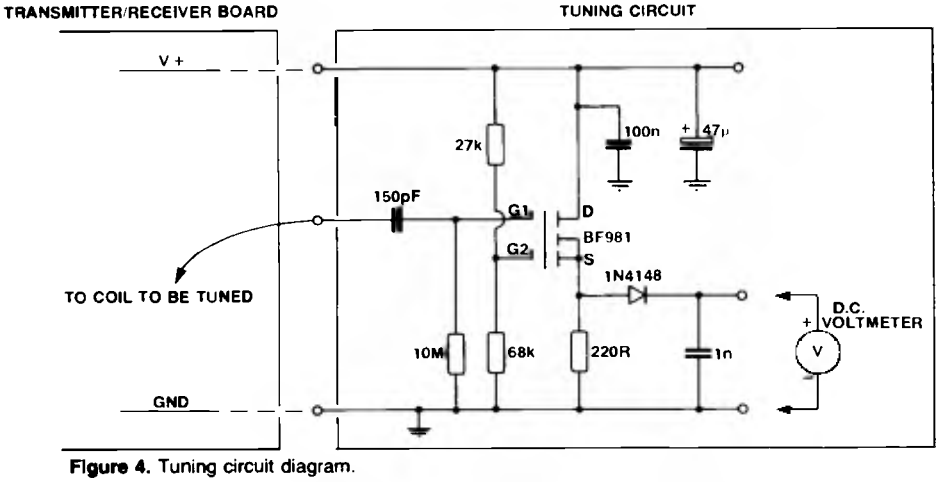
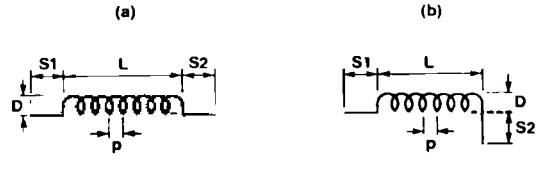
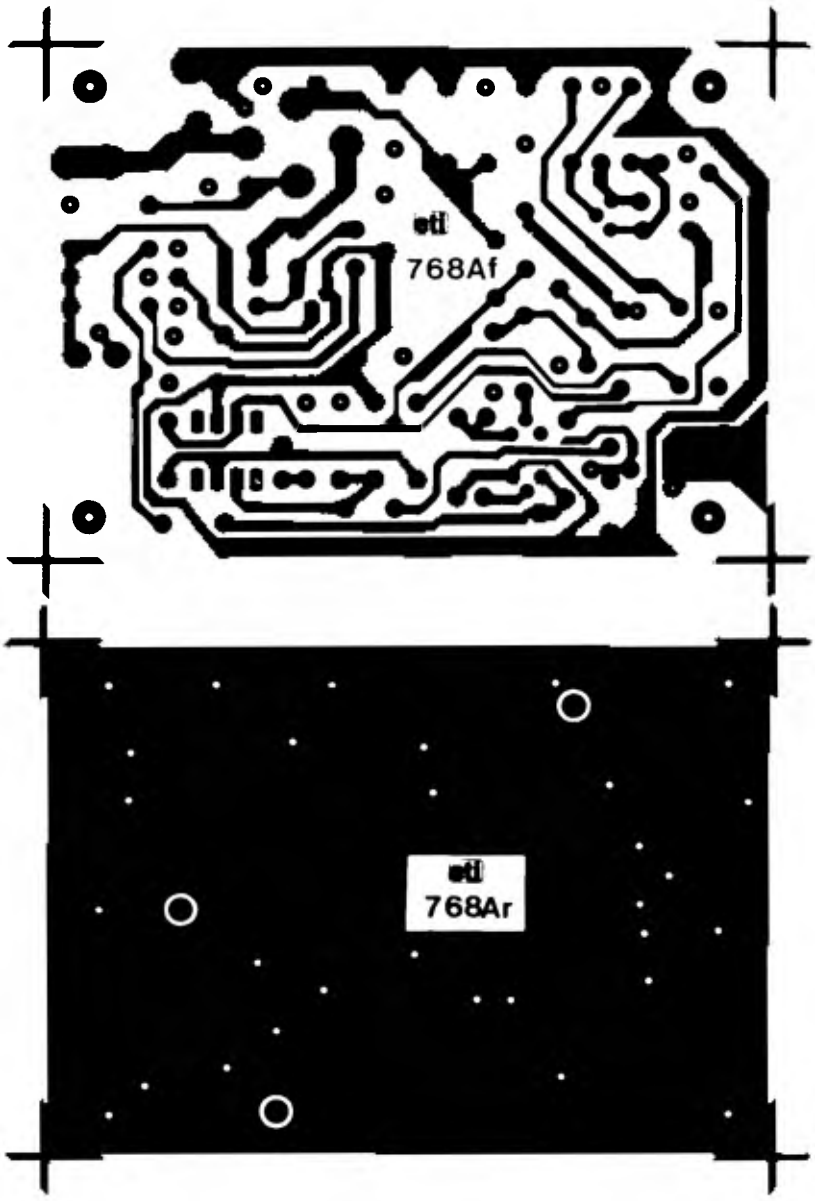


Figure 4. Tuning circuit diagram.



L = LENGTH OF COIL
D = DIAMETER OF COIL
l = LENGTH OF WIRE USED TO MAKE UP THE COIL
d = DIAMETER OF WIRE USED TO MAKE UP THE COIL
p = PITCH OF COIL
S1 = SLEEVE ONE
S2 = SLEEVE TWO
T = NUMBER OF TURNS

Figure 5. The two types of coil shapes.



coil to see whether its inductance is too high or too low for resonance to occur. The reading from the digital meter will increase as you slowly insert the ferrite screw. It generally reaches a maximum point then starts to decrease if the screw is pushed in further. The reading indicates that the inductance on the coil needs to be increased up to the maximum reading. Any further increase of inductance will kill the resonance. So to achieve the climax point, take a note of the maximum on the meter and remove the screw. Now compress the coil slightly, remove your hand from near the coil (as the human body can effect the tuning) and take a look at the reading. If it has already reached the maximum, that's fine, if not, it has either been compressed too far (having too much inductance) or was not compressed far enough. To verify which is the case, you only have to insert the ferrite screw again. If it decreases the reading, you must have compressed the coil too far, in such case, you should stretch the coil.

It is an iterative, tedious process but should not take more than 15 minutes Please consult table 1 for the tuning readings I obtained.

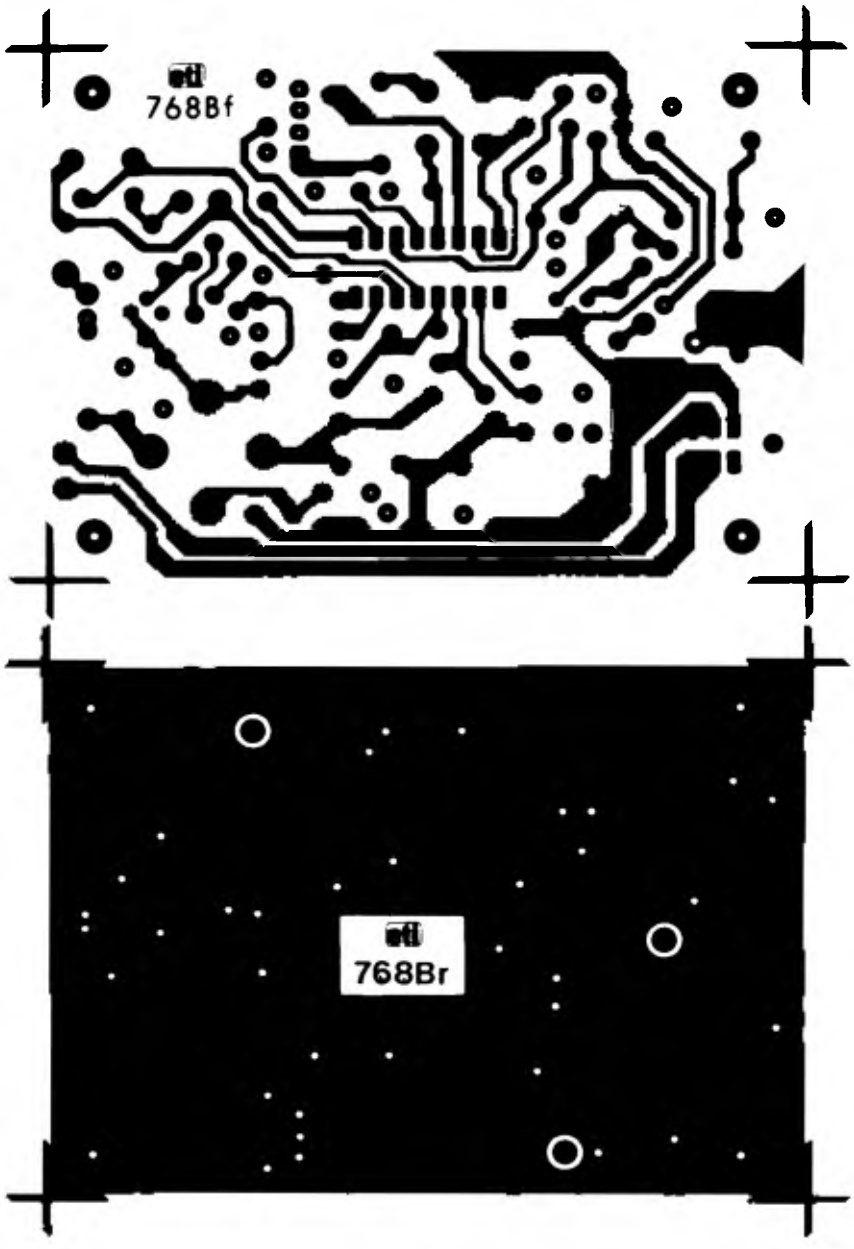
Coil L2, L3 and L4

These three coils should be treated together as they are related. To tune them, you must finish tuning L1 in the transmitter. Connect the tip of the transmitter antenna to that on the reciver via a 150 pF ceramic capacitor. The transmitter is now transmitting its carrier to the receiver. This carrier signal is needed in order to tune the coils L2, L3 and L4. Remember that if there is no mic. input signal, the voice operated switch will disable the carrier signal. Since no one has lungs big enough, some means of keeping the carrier going while carrying out the tuning process is required. To do that, please refer to the photograph. There are two tracks very near to each other, located right next to the transmitter crystal. Bridging the two tracks together with solder will bring power supply to the oscillator. A continuous carrier will appear on the transmitter antenna without any mic. signal needed. Don't forget to break the solder link when the tuning is done.

As described above, power to the tuning circuit is either taped from the transmitter or the receiver board. The signal input to the tuning circuit should be taped from the drain of the transistor Q6. When you do your measurement, capacitor C26 should be ac coupling the signal to pin 14 of the IC2. Due to the absence of the impedance existing on pin 14, removing C26 would give you a higher reading on the meter. In fact, the result shown in table 1 was obtained under such a situation (with C26 removed).

Once the tuning circuit is hooked up properly, turn on the power and take a note at the reading on the meter. Slowly insert the brass screw into coil L3 and observe the change in the reading. The fact that coil L2 and L3 are so close together and with their axis parallel make them look like a single coil. The middle gap between the two coils affects the coupling from L2 to L3, but it has nothing to do with the tuning, although the smaller the gap, the better. Therefore, make sure the screw is inserted into the coils from the L3 side, not the L2 side. Again compress or stretch coil L3 as indicated by the screw in order to achieve maximum reading on the meter. You will find L2 does not require much tuning at all as it is merely a high impedance coil to pick up the carrier signal Inserting a ferrite into L2 (from the L2 side) will deceptively increase the reading, but the increase is not due to the change of inductance, it is in fact, a better coupling between L2 and L3.

The coil which really affects your reading a lot is L4, it is a tuned band pass filter. The amplitude of the received signal, as indirectly indicated in your meter would shoot up to a climax if coil L4 resonates with the C24. In table 1, the maximum voltage obtained from the drain of Q6 is shown when L2, 3 and 4 are properly tuned. Again, don't forget to solder the capacitor C26 back when the tuning is done.



Coil L5

Tuning on this coil is not necessary simply because the turns are closely wound together (pitch is zero). Compressing and stretching it is not possible. So long as the number of turns in the coil is correct, the on chip oscillator should oscillate.

The output of the oscillator can be verified with a CRO on pin 10 of IC2 (the loading resistor R25 must be there to correctly load the oscillator output when being monitored). Alternatively connecting the tuning circuit to pin 10 should give a reading of 0.79 V approx.

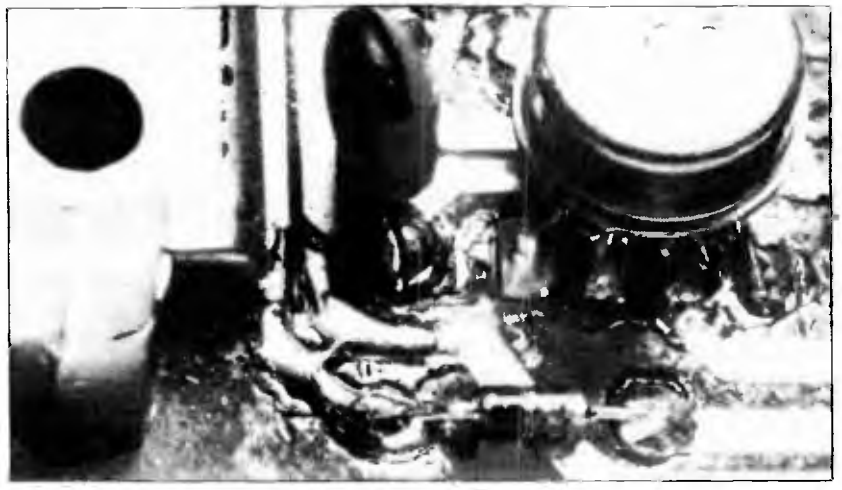
RF Transformer T1

When the coils have been tuned properly, you are ready to receive the best signal by tuning T1. The tuning circuit is not needed here. The set up is similar to the one described above; with the voice operated switch disabled and the transmitter transmitting a non modulated carrier continuously. The 150 pF capacitor joining the tip of the transmitting antenna to the receiving one should be removed to avoid overloading the receiver chip. The carrier signal will be picked up by the receiver antenna off air. Capacitor C26 has been put back into its spot. Use your multimeter to measure the dc voltage output from the internal AGC control on pin 8 while you turn the slug in the transformer. Before you start, unwind the slug on top of the transformer until it can't go any further. Then slowly wind down the slug (clockwise) and keep tracing the reading on the meter. You will experience a slow rise in the reading until it peaks, the down it goes!! The best (sharpest) tuning is the one when the voltage shown on the meter is at its peak. I can't really say what value this peak should be at because it depends on the strength of the carrier signal ▶

Table 1: Various tuning voltages obtained using the tuning circuit as described in text.

Condition: Supply at 12V
One meter long transmitter receiver antenna fixed in a 'V'-shape for more detailed conditions, see text.

		Unit 1	Unit 2
Transmitter	Voltage at drain of Q5	6.22V	6.34V
Receiver	Voltage at drain of Q6	6.15IV	5 6V
	Voltage at pin 10 of IC2 (TDA1072A)	0.791V	0.790V



Close up of the two tracks which need to be bridged during tuning.

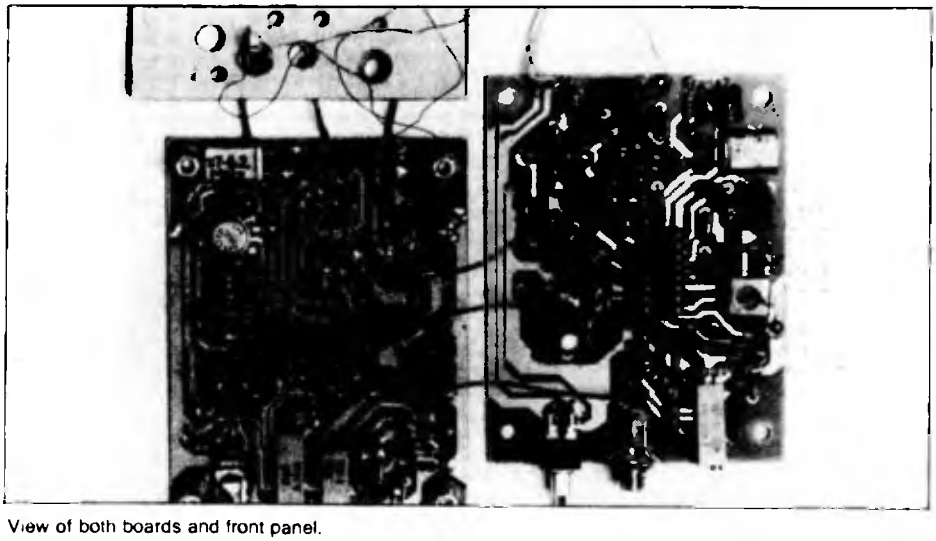
at the time. One caution: you will find your body will affect the reading as well. I suggest you turn to the slug a little, move your body back and read the meter, then repeat until you get the peaking to occur.

Testing The Unit

Get a friend to help when you try out your first test. Stand 5 metres away from each other, plus your mic. and phone onto the right sockets. Antennas are also plugged into the 2.5mm phono socket ready for action!! Each of you should carry a small, watch screw driver for tuning the trim pots.

Turn on the unit and you will see the LED glow and die away after 2 seconds or so. A lot of hiss should now be heard from the earphone. If the LED glows steadily, you may have your MOD (the trim pot RV1 labelled MOD on the front panel controls the gain of IC1 and hence the depth of modulation) turned up too high. Your breath or the ambient breeze is triggering the voice operated switch continuously. Turn it down by turning the trim pot in anti-clockwise fashion.

SEN stands for sensitivity of the voice operated switch. I personally find that turning the MOD up and SEN down (by turning it clockwise) works quite well. Having the MOD up means you don't need to shout. On the other hand, low SEN means ambient noise won't trigger the unit. Trim pot RV3 controls the volume output on the headphone. Turning it clockwise will reduce the volume output. If everything works fine, just follow the protocol described in the last issue when you communicate. (Continued page 108)



View of both boards and front panel.

Brass rod, ferrite slug and tuning circuit.

Coil Construction

To get the idea across efficiently, some jargon will need to be defined (as shown in figure 5).

The physical information for each coil is shown in table 2. Although the data shown in table 2 is quite different for each coil, the way they are made is not all that different. First cut the wire to the exact length as indicated in table 2. Get a sharp blade or scalpel to scratch away the insulating coating on the sleeves for soldering purpose. Wind it up on the specified drill bit for the specified number of turns. It does not matter if you don't have any pitch between turns when you wind it up on the drill. As soon as you release it, it stretches itself anyway. Solder one sleeve onto the pad first, then refer to the picture shown here to get some idea of what the final pitch is like. Pull the other end of the coil with a tweezer to achieve roughly the same pitch and solder it down. This is an important step to ensure you are not too far from the maximum point even the start of the tuning process.

Coil L2 and L3 have one of their ends through the pc board and soldered on the bottom side. They take up a shape as shown in figure 4 (b). As mentioned ini the text, the gap between L2 and L3 should be as small as possible to maximize coupling between them. When it comes to L5, some way of stopping the coil from stretching is necessary as there is no pitch. I achieved that by putting one layer of celiotape onto the winding. Trim the extra bit of tape on the ends of the coil then carefully remove the coil from the drill bit.

Table 2: Information on winding up the coils in the circuit. Please refer the symbols used here to figure 5.

Coil	I	T	d	P	D	S1	S2	L
L1	160	8	0.63 (22 SWG)	1 (approx.)	5.1 (approx.) (13/64 inch)	3	3	9 (approx.)
L2	63	3	0.63 (22 SWG)	0.5 (approx.)	5.1 (approx.) 13/64 inch)	2	4	3 (approx.)
L3	160	8	0.63 (22 SWG)	0.5 to 1 (approx.)	5.1 (approx.) (13/64 inch)	4	4	5.5 (approx.)
L4	190	10	0.63 (22 SWG)	1.5 to 2 (approx.)	5.1 (approx.) (13/64 inch)	3	3	11 (aprox.)
L5	323	19	0.315 (28 SWG)	ZERO PITCH	5.1 (approx.) (13/64 inch)	3	3	6 5 (approx.)

NOTE: The pitch (p) and length of the coil (L) shown in the table is only rough. Their actual length depends on your tuning. All dimensions shown in millimetres (mm) unless otherwise noted

Errata

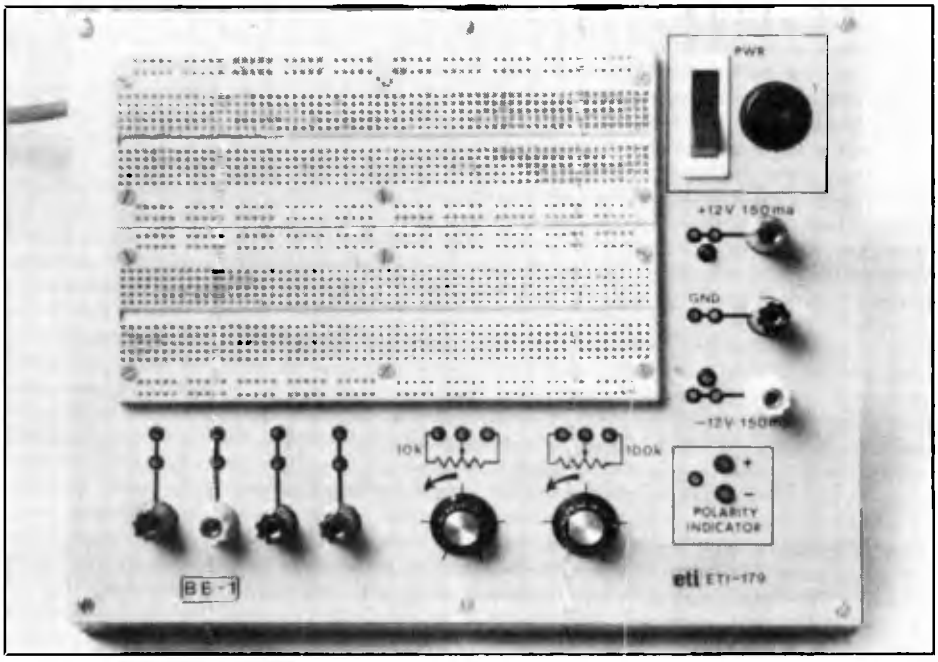
After the basic functions worked, I made several measurements of the transceiver's performance. At first the results were disappointing but these were improved by a few minor changes. Several component values needed to be corrected.

Your circuit will be correctly assembled if you follow the overlay diagram or parts list. The values on the schematic are incorrect. The changed values are IC1, R4, 5,7,9,10,19,32 and C5, 10, 11, 21, 24, 30, 41.

AN ANALOGUE BREADBOARD

A breadboarding socket on its own is useful, but it needs to be combined with an integral power supply, some hardware and support circuitry if a really versatile system is to be realised.

Peter Phillips



The top view. Front panel artwork for the ETI 179 was too big to fit in the magazine. If you require it, contact ETI readers services on (02) 693 6666.

THE BREADBOARD HAS traditionally been the developmental tool of circuit designers, as the ease of component replacement allows 'fine taning' of the circuit before its eventual placement on a pcb. Educational institutions often use breadboarding systems for practical sessions of electronics, as component wastage is minimised. However, on its own, a breadboard is simply a means of interconnecting and supporting components. Any external attachments to the circuit, such as test equipment, potentionmeters, switches, the power supply, input signals etc, need to be arranged around the board and connected in whatever way possible. This can result in the traditional 'rats nest', resulting in confusion and circuit errors. More sophisticated circuit development systems offer a breadboard mounted on a box that contains external support for the board. It sound simple, and it is. The problem is: trying buying one that doesn't cost an arm and a leg. This article presents a design that includes all the pcb layouts and panel artwork to allow constructors to build their own, customised system. The design is intended for analogue applications, and features a dual polarity power supply and a sensitive voltage polarity indicator. A digital breadboarding system will be presented later and will include support circuitry peculiar to such a system.

The Circuit Principles

The circuitry of this project is relatively simple. One pcb design (PCB-1) contains the dual polarity power supply and the polarity indicator. PCB2 contains the hardware and the socket pins that enable interfacing between the breadboard and the power supply.PCB3 hold to two on-board potentionmeters and the connections to the outside world. The design is based

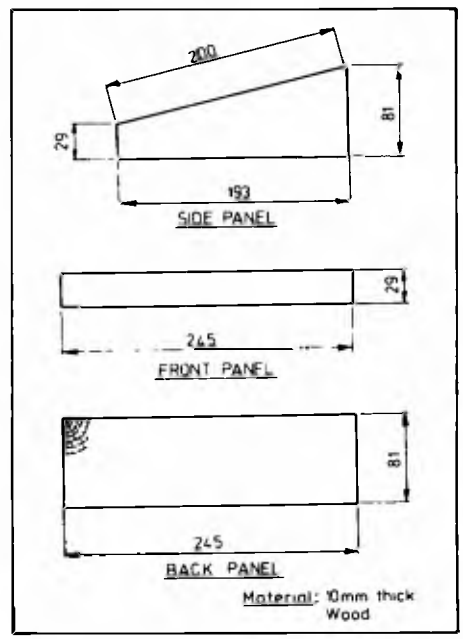


Figure 1: Cutting diagram for the box. This is only really necessary if you want to use a front panel like ours. Otherwise you can dimension the thing to please yourself.

upon my experience of the requirements for analogue circuit development. Cost has been minimised by using garden variety components, which perforce means a relatively basic, but still very versatile unit.

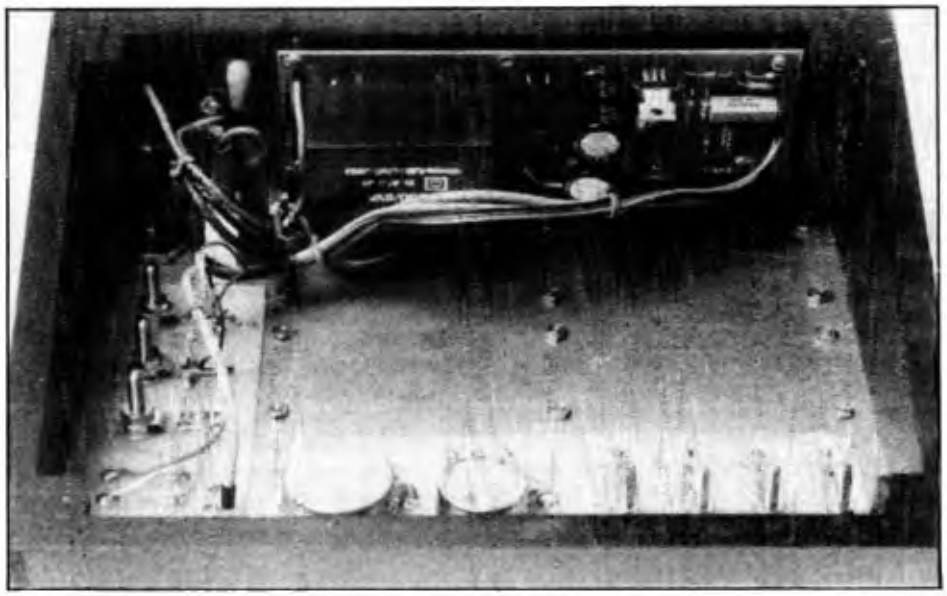
Naturally, readers can add, alter or delete sections as required. For example, PCB-3 could be used to mount switches instead of potentionmeters, or two of these boards could be used, one for the pots, the other with switches. The power supply will not handle currents greater than around 150 mA per side unless a higher VA rated transformer is used. However, in the unlikely event that higher currents are needed, an external power supply can be interfaced via the 4mm terminal posts provided. Heavy leads are connected to the terminals, which then connect to the breadboard via the associated socket pin(s) with 0.6mm wire.

Customising the Design

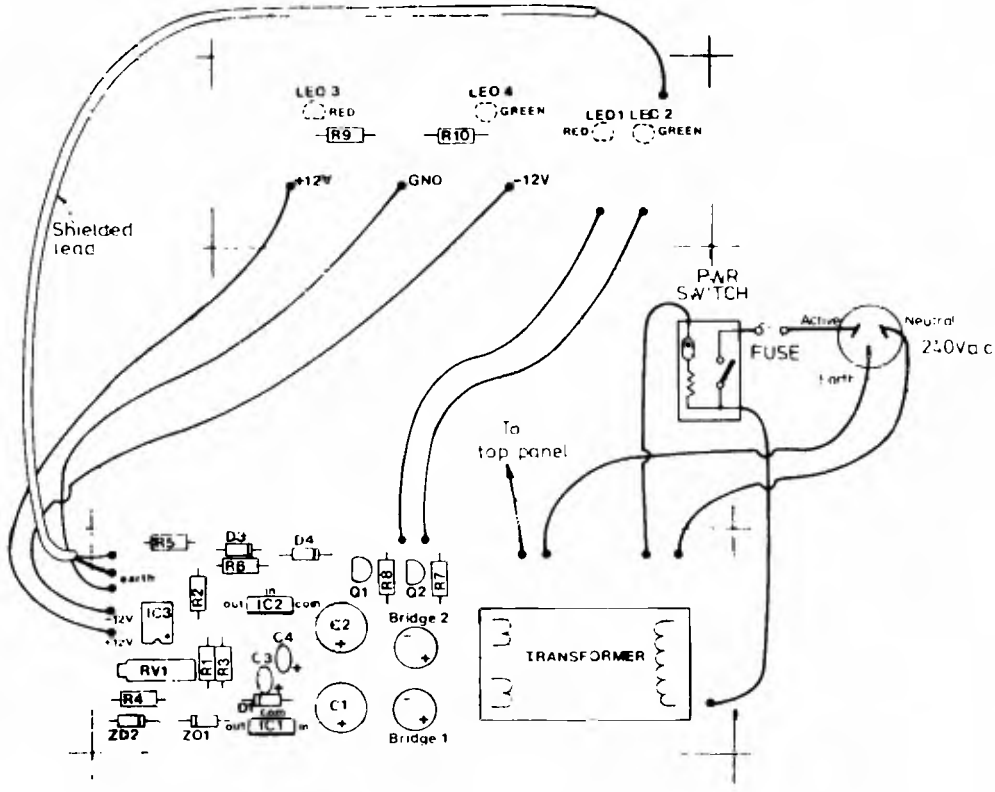
The mounting framework for the prototype, consisting of a wooden box fitted with an aluminium top may suit those with the necessary workshop facilities. However, any equivalent construction would do, although the metal top is recommended to act as a ground plane. A sloping top was incorporated to facilitate viewing the breadboards, but a simpler construction would result from a flat box. The power supply board (PCB-1) was mounted at the rear of the box in the prototype, but can be positioned anywhere it fits. I attached two breadboarding sockets (840 hole size), but one would probably be sufficient for most applications. A bottom cover of timber or metal should be added to the box, and rubber feet will provide stability. To further extend the versatility of the BB-1, mounting flanges for extra pots, switches and devices could also be attached to the unit.

If the supplied top panel artwork is to be used, the layout of the prototype is mandatory. Develop your own artwork and the sky's the limit. There are various methods of constructing the top panel. For example, the top could be made from one large pcb section (245mm x 200mm), etched using the supplied pcb layouts positioned accordingly. The component side could then be painted and screen printed using the supplied design. If screen printing facilities are not available, press-on lettering and hand drawn symbols and lines could be applied. This latter would require lacquering to protect the artwork.

Alternatively, an aluminium top with hand-painted artwork could be used. Treatment of the aluminium top should at least include coating with lacquer, perhaps preceded by polishing and dipping in caustic soda. This latter treatment should be done with some care, as irritating fumes are released during the process. Otherwise, the aluminium could be painted, after application of a suitable primer, and the artwork applied to the painted surface. The prototype was constructed using an aluminium top covered with a Scotchcal panel. The pcbs (2 and 3) were then laid to the underside of the top panel by drilling holes to allow mounting of the necessary hardware through the panel onto the pcbs. This method results in the pcbs being attached by the hardware, allowing trackside accessibility from underneath. An alternative approach is to make each pcb, and then mount the boards on top of the panel. This would require rectangular cutouts in the panel, and fixing with screws at each corner of the pcb. This 'modular' approach, with its inherent flex-



Bottom view, looking towards the back of the unit. PCB1 holds the transformer, PCB 2 is to the left, and the pots carried by PCB 3 are almost obscured in the foreground. This view also shows how the box was built. Simple!



ibility would allow any arrangment sought, while still offering a good-looking end result.

Constructing the BB-1

Commence construction by building the box. Those with a flair for carpentry will probably build a box with mitred corners and a recess to hold the top panel. (The prototype wasn't; just a simple butt connection box, painted matt black, then sprayed with satin enamel lacquer).

The next step is to cut the top panel, trimmed in size to suit the box. The position of the holes and cutouts can be determined either from the artwork or by placing the pcbs and the breadboarding socket(s) into place, and cutting out accordingly. If a Scotchcal front panel or a screen print is being used, this could be applied first, and used as a reference for the various cutouts. Once the top panel has been completed, PCBs 2 and 3, the breadboarding socket(s) and the power switch (and fuse if used) can now be mounted in position. If the pcbs are mounted as in the prototype, that is, beneath the top panel, held by the hardware, it is likely hole alignment may not be exact. For this reason, you may prefer to drill the top panel according to the artwork, then drill the pcbs using the top plate as a template. Getting perfect alignment is impossible, but with care, good results can be obtained. This part of the construction is relatively time consuming and fiddly, as care must also be taken not to damage the top panel artwork, or to create any short-circuits between the panel and the components passing through it.

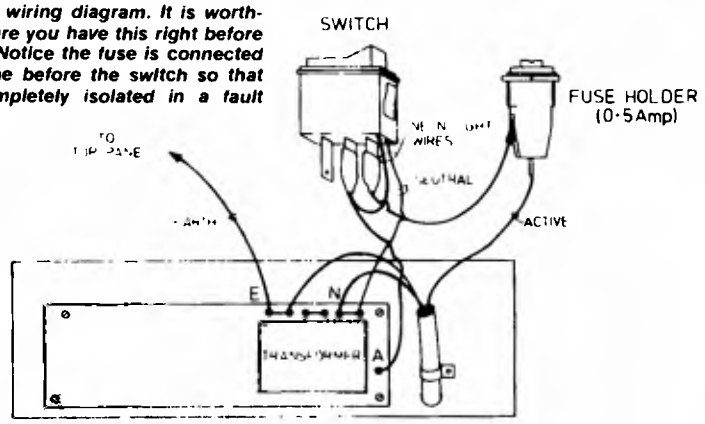


Figure 2: Mains wiring diagram. It is worthwhile making sure you have this right before you switch on. Notice the fuse is connected in the active line before the switch so that the unit is completely isolated in a fault condition.

PCB-1 should now be built, as per the layout diagram, but should be fitted only after all wiring, testing and adjustments have been completed. This pcb was fitted to the prototype using spacers and self-tapping screws into the timber back. If a bigger transformer than the specified one is used, it should be mounted directly on the case, earthed and connnected with leads to PCB-1. If a power supply with increased power characteristics is used, heat-sinking the regulators will be necessary.

The choice of the power switch should be made with some care as it is likely this switch will get a lot of use, requiring a rugged switch if reliability is to be achieved. Use of a miniature switch is not recommended. The illuminated variety was employed as it provides a positive indication that the power is on.

Four LEDs are incorporated on PCB-2, two adjacent to the +12 and −12 termi-

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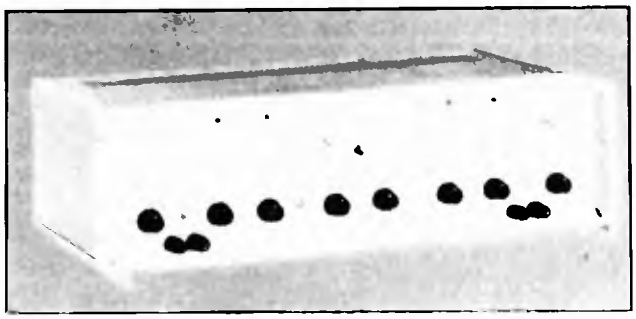

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	0-70V	0-2A to 10A

DUAL OUTPUT 0-30V 0-1A to 2A

MULTIPLE OUTPUT 0-30V 0-2A to 5A

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nals, two more for the polarity indicator. Pin-point LEDs are specified; green for both negative voltage indicators, reds for the positive indicators. They mount directly onto the pcb, through a 5mm hole drilled in the top panel. A piece of 4mm black plastic tubing over the bottom of the LEDs will enhance their light output and protect the leads from shorting to the panel. Current limiting resistors R9 and R10 for LEDs 3 and 4 should be soldered on the track side of PCB-2. The 4mm terminal posts on both PCBs 2 and 3 should be soldered directly to the pcb track with their connecting lugs. If VCU style potentionmeters are used for PCB-3, they can be soldered to the pcb lands directly by forming the lugs to suit. The flat section will be incorrect to suit a screwed dial knob, requiring another flat to be filed onto the shafts. Metric style pots overcome this problem, but will require connection with wire to the pcb lands.

The earth wire from the mains is terminated on PCB-1, and is subsequently connected to the ground terminal post of the unit via the power supply wiring. However, a separate 7 amp rated wire should be connected to the aluminium top panel. This not only provides protection, but serves to ground any noise pickup. The pcb mount transformer is not earthed, as it is double insulated. However, if a conventional mount transformer is used, it should also be earthed.

Construction of the pcbs is straight forward; just follow the layout diagrams and watch component orientation when building them. The IC socket pins associated with PCBs 2 and 3 can be obtained either by sacrificing IC sockets, or by purchasing insulated IC socket strips. The gold insert, machined variety are recommended to stand up to the type of use envisaged. (Those used in the prototype were supplied by George Brown). Molex pins would work, but are unlikely to give reli-

PARTS LIST

RESISTORS — All ¼ watt 10% unless otherwise specified.
— all values in ohms.

R1, R2, R5, R6 ..... 10k
R3 ..... 220k
R4 ..... 68k
R5, R6, R7 .....
R8, R9, R10 ..... 1k

POTENTIONMETERS RV1 ... 10k, 10 turn trimpot
RV2 ..... 10k linear, panel mount
RV3 ..... 100k linear, panel mount

CAPACITORS
C1, C2 1000
C3, C4 ..... 2.2 tantalum.

SEMICONDUCTORS
Q1 ..... BC547 or similar
Q2 ..... BC557 or similar
D1, D2 ..... IN4004 or similar
D3, D4 ..... IN914 or similar
ZD1, ZD2 ..... 5V6 400mW Zener diode
IC1 ..... uA7812, T0220 voltage regulator
IC2 ..... uA7912, T0220 voltage regulator
IC3 ..... uA714
Bridge 1 and 2 ..... W04 or equiv.
LED 1 and 2 ..... Pinpoint red LED
LED 2 and 4 ..... Pinpoint green LED

SWITCHES
S1 ..... 240 volt mains switch (illuminated)

TRANSFORMER
T1 ..... PCB mount, PL30/5 VA or equiv.

MISCELLANEOUS
PCB or vero board; Scotchcal front panel; timber for case; light gauge aluminium sheet 220mm x 245mm; 7 x 4mm terminal posts; 20 insulated IC socket pins, gold insert, machined variety; 2 control knobs; 4 pcb supports, rainbow cable hook-up wire, 240 lead and plug; cable clamp; lugs, 840 pin breadboard socket(s); fuse holder; 0.5 amp fuse.

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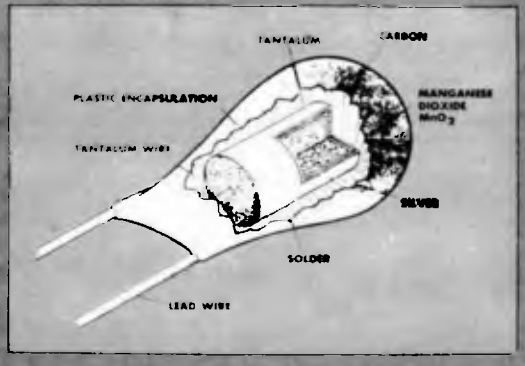

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able long term service in this application. The socket pins solder directly to the pcbs, through a 3mm hole in the top panel. The interconnections between PCBs 1 and 2 are shown in figure 3. Note particularly that a shielded lead is required to connect the polarity indicator input on PCB-2 to its circuitry on PCB-1.

Commissioning

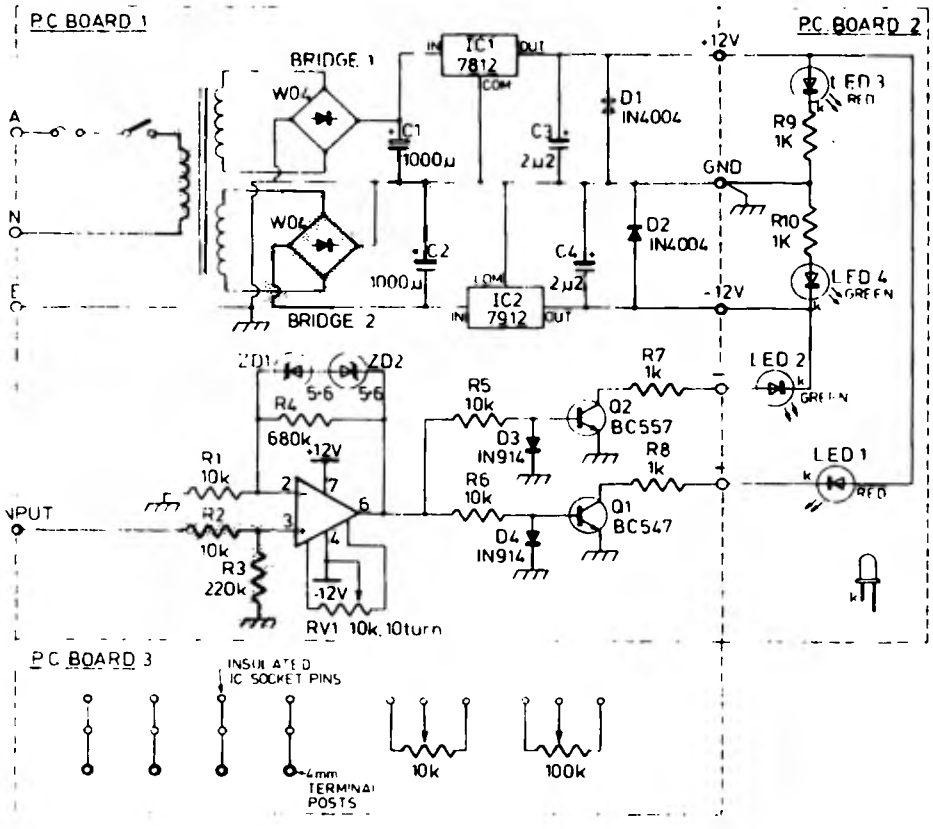
Once all wiring is complete, and final checks confirm that PCBs 1 and 2 have all components correctly polarised, apply power to the unit. The two voltage indicator LEDs should light to show the presence of the +12 and −12 volt rails. If not, determine if these voltages are in fact present. A likely problem is incorrect orientation of diodes D1 and D2, or of the regulators. Note that the 7800 series has different connections to the 7900 series, but that orientation on the pcb is the same for both devices. If voltage is present, check the LED orientation. If all is well, it remains to adjust the offset for the polarity indicator. This should ideally be done with a voltmeter connected to pin 6 of IC3 to measure the dc output voltage. Connect the polarity indicator's input terminal to ground, and adjust RV1 until the dc voltage at pin 6 is exactly 0 volts. Allow a few minutes for everything to stablise before performing this adjustment. Once this is complete, both LEDs associated with the indicator should be out. Applying a positive input voltage greater than 10mV should cause the red LED to turn on; similarly, the green LED should light for an equivalent negative input voltage. The maximum input voltage should not exceed 24 volts. Finally, install PCB-1 into position and tie the wiring neatly into looms.

Using the BB-1

The BB-1 is designed to facilitate the development of analogue circuitry, by providing the necessary support to the central object of the unit; the breadboarding area. Next month will provide some interesting practical op amp circuits for you to experiment with, but some important do's and don'ts are worth mentioning now. The breadboard sockets are the most expensive item of the unit, and require special treatment if they are to last. It is important to only ever insert leads and wires into the sockets that do not exceed around 8.7mm. Telephone wire is useful as interconnecting wire, and a range of colours is recommended in various lengths. Try to use wires that are the right length to keep the circuit neat and to prevent random noise pickup. Develop a colour code standard, e.g., red for positive rail, white for negative, black for ground, and only use wires with clean bared ends. Broken pieces of wire lodge in the breadboard, caused by re-using old wires, will quickly render the socket useless. Ideally, a pair of wire strippers should be on hand to bare the wire without causing a nick in the wire when it is stripped. Bare the wire to expose around 5 to 6 mm only; too

ETI-179 How It Works

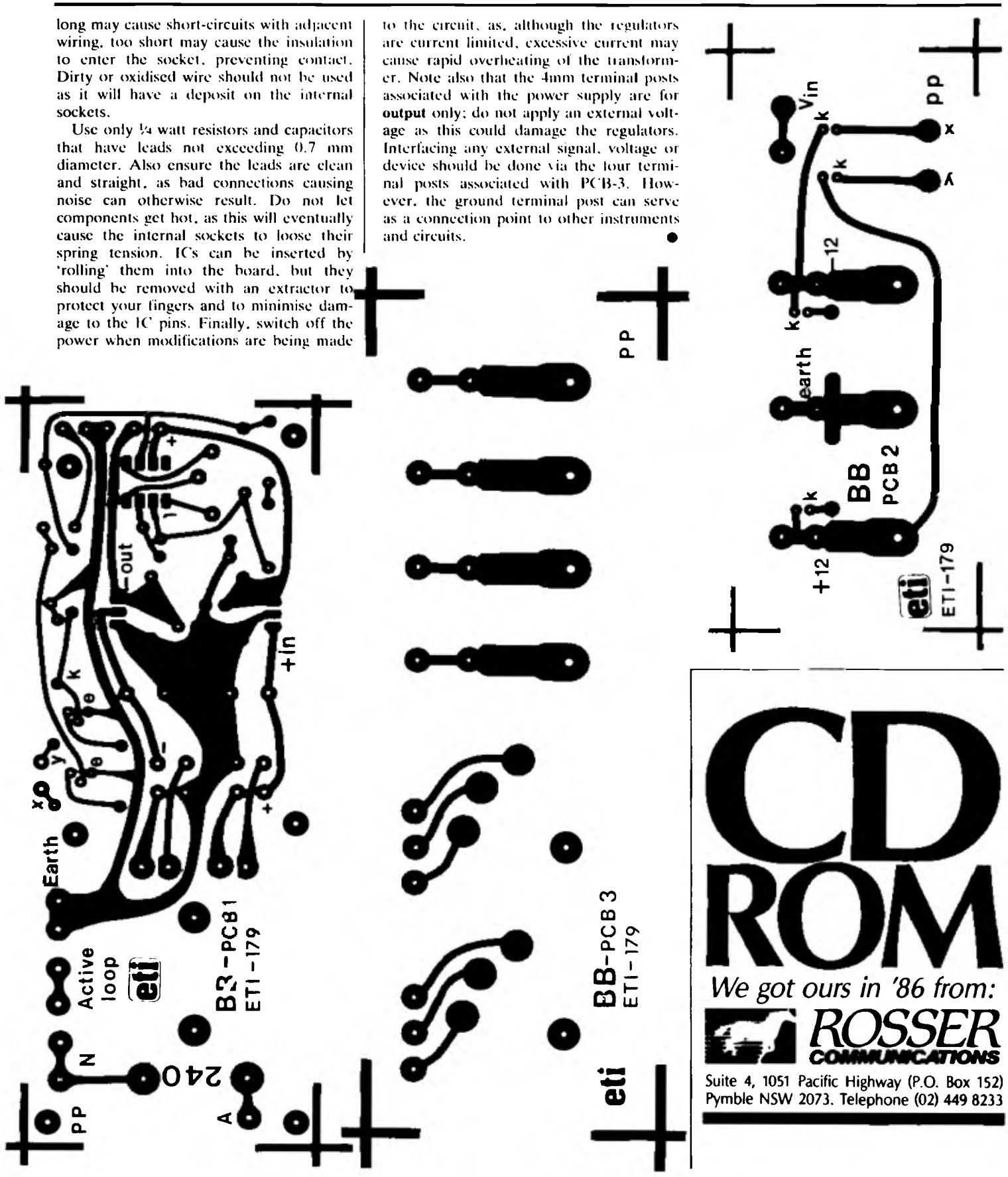
The electronics for this unit are mainly contained on PCB-1, although indicator LEDs and outputs/inputs are on PCB-2. The dual polarity power supply uses two 12V, three terminal regulators, supplied by two diode bridges in turn connected to the isolated secondary windings on the transformer. Capacitors C7 and C2 filter the bridge outputs. Capacitors C3 and C4 improve the transient response of both regulators, and should be tantalums. The diodes D1 and D2 allow reliable start up of the regulators by eliminating any reverse voltages that may be present at the regulator outputs. The output voltages areestablished at +12 V and −12 V (within 5%) with respect to ground, and are applied to PCB-2 for subsequent connection to the breadboard. The transformer secondary voltages are 15V ac each, and the suggested transformer has a rating of 5VA, limiting the available current per side to around 160mA. At this current, no heatsinking is needed for the regulators. Varying the output voltages by using different regulators would require a suitable transformer matched to the required voltages.



The polarity indicator is based on a 741 op amp, connected as a high gain, non-inverting amplifier. R1 and R4 set the gain at around 68, and ZD2 and ZD2 limit the output voltage of the 741 to plus or minus 6V. This prevents saturation problems, and minimises the effect of skew thereby allowing a quick response. The indicator LEDs 1 and 2 are driven by transistors Q1 and Q2 which operate when the output voltage of the op amp increases above 0.6 V. Q1 requires a positive voltage to operate, supplied when the input to the op amp exceeds +10 mV. Similarly, applying −10 mV or more to the input will cause Q2 to switch on. Diodes D3 and D4 protect the transistors against reverse conduction. The input resistance of the circuit is around 200k ohms, allowing the circuit to be used to monitor voltages in most applications. R3 is used to limit random noise pickup when the input is left open-circuit. The maximum input voltage is 24 V. Offset adjustment is provided by RV1 to ensure the output voltage of the 741 is zero volts when the input is connected to ground.

long may cause short-circuits with adjacent wiring, too short may cause the insulation to enter the socket, preventing contact. Dirty or oxidised wire should not be used as it will have a deposit on the internal sockets.

Use only ¼ watt resistors and capacitors that have leads not exceeding 0.7 mm diameter. Also ensure the leads are clean and straight, as bad connections causing noise can otherwise result. Do not let components get hot, as this will eventually cause the internal sockets to loose their spring tension. ICs can be inserted by 'rolling' them into the board, but they should be removed with an extractor to protect your fingers and to minimise damage to the IC pins. Finally, switch off the power when modifications are being made to the circuit, as, although the regulators are current limited, excessive current may cause rapid overheating of the transformer. Note also that the 4mm terminal posts associated with the power supply are for **output** only; do not apply an external voltage as this could damage the regulators. Interfacing any external signal, voltage or device should be done via the four terminal posts associated with PCB-3. However, the ground terminal post can serve as a connection point to other instruments and circuits. ●



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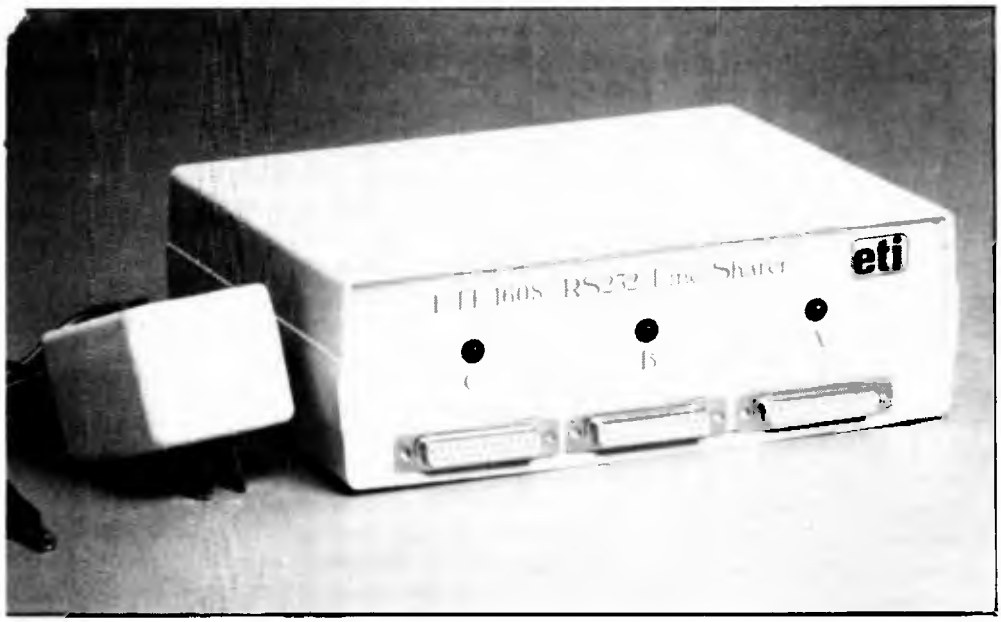
S. K. Hui



IN OUR OFFICE, we have DB25 sockets in the wall to provide connection to the local mainframe. The problem is we don't have enough, so that a single socket must be shared by the IBM-PC, the plotter for our CAD system and the line printer. To add to the problem, we need the IBM to act as host for either the plotter or the printer, and for other terminals in the network to be able to drive the printer. At the moment we solve the problem of connecting all this together by plugging and unplugging cables as required. It's messy, frustrating, and what's more, wears out the plugs in a surprisingly short period of time.

What we need is a switch. It needs to be able to switch a few ports, and be bidirctional as well so that it doesn't matter whether one is dealing with inputs or outputs. It would also help if it had the additional flexibility of being able to be configured to fit the wiring pattern of individual units.

This is the motivation behind the ETI-1608 RS232 Line Sharer. Although the application of this project seems to be limited to the professional market, the design is flexible enough to cater for individuals. It's features could be reduced (along with the cost) during the construction process to suit hobbyists. No extra work is required to achieve this economical version except putting less components on board.

The fully configured version can switch one input port to any one of the three output ports (8 lines per port) at a flick of a switch. But that is not the end of the story. The unit can also be used in a reverse sense, allowing three computers to share one peripheral such as a line printer. Each port can be configurated individually to save the pain of having another RS232 break-out box external to the unit.

Artwork available from ETI reader service ph. (02) 693-6666. Completed circuit boards and panels may be obtained from RCS Radio (02) 587 3491.

Design approach

After a glance of the circuit, I can hear a lot of you say: "What, no IC's??" The answer is that this is a SIMPLE, but NOT a stupid design. No LSTTL multiplexers, no CMOS analogue switches and no RS232C transceiver chips are used at all. The majority of the components on board are just relays, relays and relays again. Don't run away with the idea that I earn commission from a relay company. There are practical reasons behind it.

To be honest, my initial thoughts led me naturally to think in terms of LSTTL multiplexers, decoders or CMOS analogue switches. In fact, my first attempt was based on the good old analogue multiplexer 4052B. The device has eight analogue switches inbuilt, requiring four ICs only to switch up to four ports. Unfortunately though, it can only switch analogue voltages up to ±9V. The RS232 standard permits transmission of voltages up to ±25V. Although a lot of equipment in the market uses ±12V, it is still a little too high for the 4052B switches.

So why not transpose the RS232 voltages down to TTL logic levels and do all the switching there before reconverting back to RS232 level?? I did exactly just that in my second attempt. It turns out that there are problems with this approach too. To allow total flexibility, each port has to be configurable, so each pin has an equal probability of being either an input or output pin. In other words, an RS232 driver and a receiver gate will have to be reserved for each pin on the connector. Additionally, each line to be multiplexed in logic level will have to have a directional control. Even if you consider switching eight lines (instead of 25) per port, the number of gates required will be horrendous. If fact, the cost of gates is similar to the cost of relays used in my final design. Furthermore a circuit that uses this many gates will be more complex and expensive than necessary. After long contemplation, I finally decided on the relay approach. It's simple and economical to build, and most important of all, simple to use.

One of the great advantages of using relays is that they pass signals in any direction, thus eliminating the problem of having directional control on each line. Secondly, relays can switch the RS232 voltages (±25V) quite comfortably without breaking down. Furthermore, the finite mechanical life usually associated with relays does not seem to be a problem here since its nearly infinite when switching

25V signals continuously. Even on the assumption that the work load in the office requires the lines to be switched 100 times a day, it will be years before any of the relays bust.

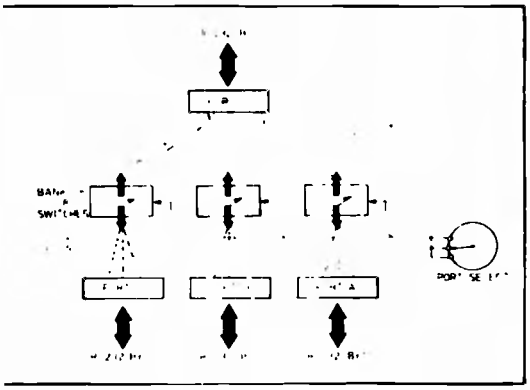
The functional block diagram of the circuit is shown in figure 1. Port D can be made to connect to any one of Ports A, B or C by the selector. There is no restriction on which is the input or the output port so long as the two ports connected have a matched configuration. The output of the selector controls the relays which are arranged in three banks. Each bank can accommodate up to eight individual relays and will be energized (on) or de-energized (off) together.

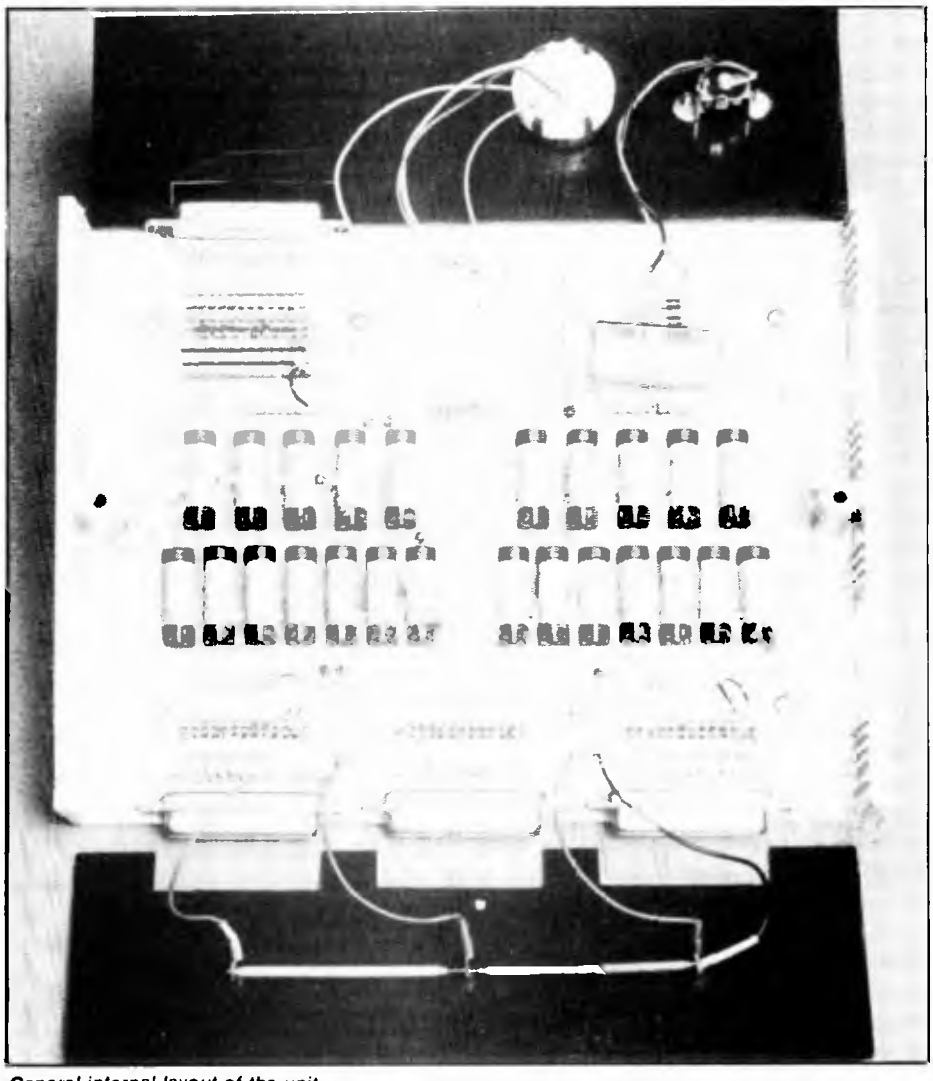
There is no reason why you should not put in less relays if the number of lines that need to be switched is less than eight. Note that the input and output of the relays goes to nowhere except to the single-in-line sockets. This feature allows maximum flexibility in configurating individual ports independently. Pushing the idea further, you could even multiplex general purpose analogue signals (either in current or voltage) from port D to either A, B or C.

According to the RS232 standard, no matter what the configuration, pin 1 and pin 7 of the DB25 connector are always the same. Pin 1 is the chassis and pin 7 is the signal ground. It is a waste of relays to switch these lines. In this design, pin 1 on each port is joined together by tracks on the pc board. There is a similar arrangement for pin 7 as well, so the eight switching relays are only reserved for switching signals only.

Construction

The only semiconductors on board are the two diodes. It is almost impossible to go wrong electrically when you build this circuit up. The only thing worth discussing is the mechanical side of the construction. Even then, to be sure everything fits nicely into the box first time without too much bending or twisting, only a few sec-





General internal layout of the unit.

Accessories of the unit. The plug with the matching chassis mount socket (SK1) the selector and the sight in line socket (SIL).

ETI 1608 — PARTS LIST

Resistors

R1, R2, R3.....150R (0.25W, 5% tol.)

Capacitors

C1.....1000µF, 16V (elec.)

Semiconductors

LED1, LED2, LED35mm. dia. red LED

D1, D2.....1N4004

Miscellaneous

Four female, soldering type DB25 connectors and a 2.1mm chassis mount socket for the plug pack (Jaycar Cat PS-0516). Twn strips of single-in-line ic sockets with 20 holes per strip. Twenty four 5V reed relays, they can be obtained from Hi-Com Unitronics or Tandy Electronics. A double-sided pc board and three LED holders. A plastic box (has to be exactly the same as the one shown in the picture) with nine self-tapping screws and some different colour hook up wires. Two scotchcal panels, one for the rear and one for the front panel of the box. The last thing you need is a 3-pole, 4-way selector switch and a 180mA (m.n.) 6V dc plug pack.

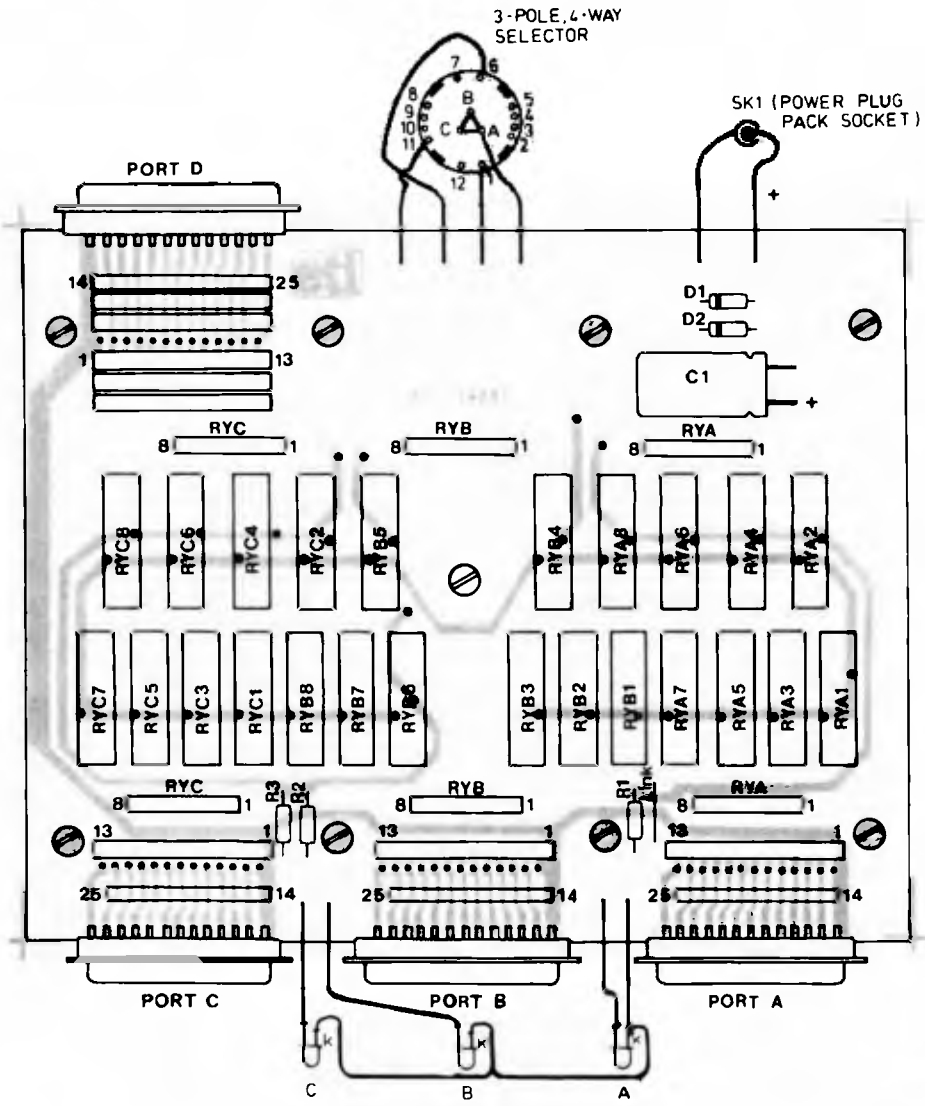
onds of patience is all you need.

To avoid flying leads to connect all the sockets, we have used a double sided board, and taken account of the fact that the rows of pins fit snuggly around the thickness of a typical pc board. This means the pins on a cheap panel mounting DB 25 can be soldered directly to the board. It looks much tidier and it's much quicker. The only penalty is that you have to get the position correct.

The first thing to do is check the board to make sure there are no bridged and open circuit tracks. Next, put in the DB25 connectors by plugging the board into the gap between the two rows of pins of a female DB25 connectors. Take your time to align the pins with the copper fingers (tracks) located on the edges of both sides of the pc board. The row with 13 pins should be soldered on the top (component) side of the board. Push the connectors in as far as they can go and solder the pins onto the copper fingers directly.

Next to be assembled are the feed-though wires which need to be soldered on both sides of the board to link tracks up. This step however, is unnecessary if the board you have is plated through. Now you can put in your relays and the single-in-line ic sockets. They come as a strip with 20 holes on it. I obtained mine from Geoff Wood Electronics in Sydney. If you have plenty of 24 pins or 40 pins standard ic sockets in your junk box there is no point in wasting them. You simply cut the middle part of the socket out to obtain the strip ready to be soldered onto the board.

Now it's time to work on the plastic panels. Mark the shapes to be cut out and holes to be drilled on the front and rear panels by following the scotchcal panel artworks shown in this article. Cut the plastic panels BEFORE sticking the scotchcal panels on to obtain a smooth panel. It will be very difficult to drill and file the plastic panels with the scotchcal



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panels already on without at the same time, twisting, or wrinkling it.

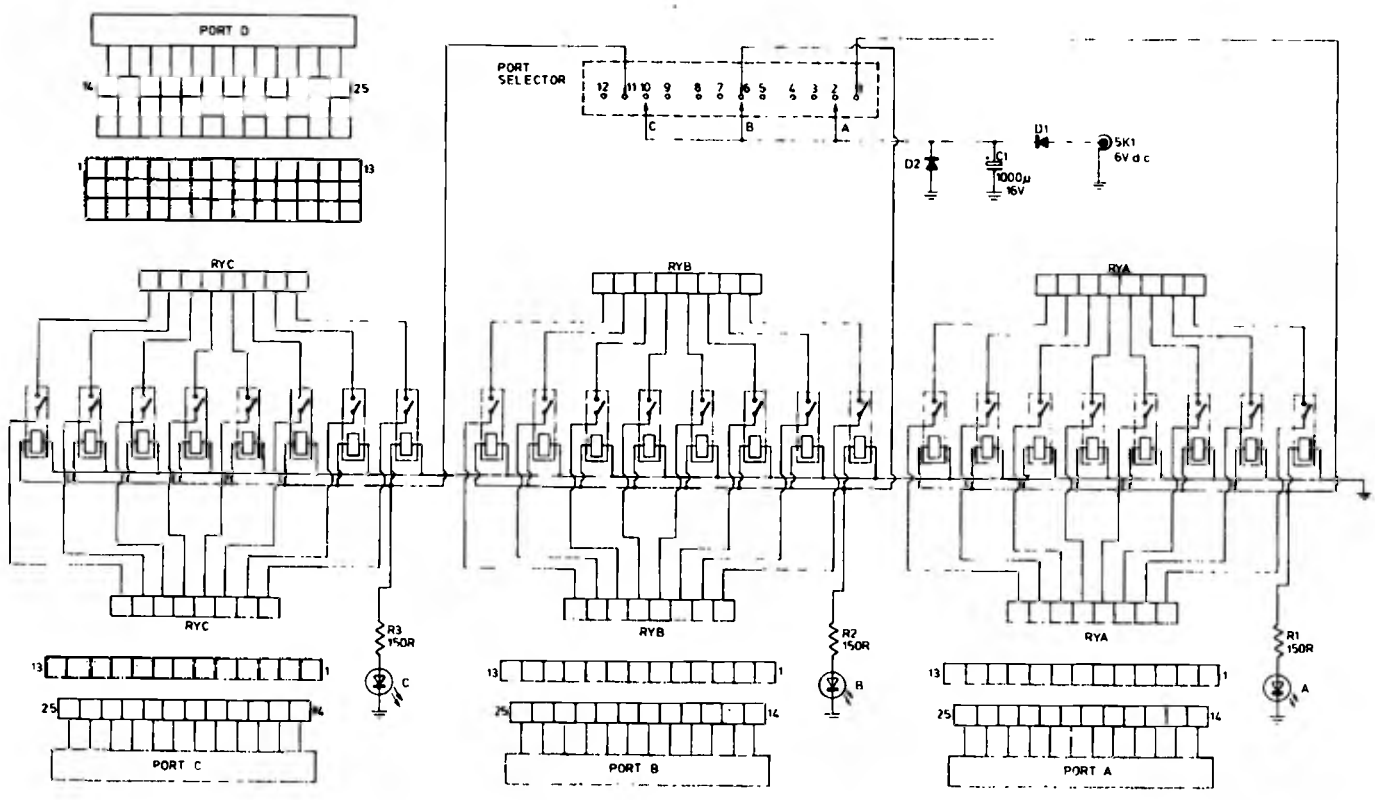
There is no need to mount the DB25 connectors onto the flimsy plastic panels. They will simply crack when you plug in or unplug something onto the connector. The strength to hold them in place comes entirely from the 25 pins, which are soldered firmly onto the board. The board itself is secured to the plastic studs sitting on the floor of the box by nine self-tapping screws as shown in the picture.

Before you put anything on the plastic panels such as the LEDs or the port selector, make sure you can slide the pre-cut plastic panels down the slots on the box comfortably. When everything seems to fit properly, remove the panels and stick down the scotchcal panels. The holes on the scotchcal are then cut nicely by using a sharp scalpel and tracing the outline of the holes and the slots already cut on the plastic panels. The accessories are then put on the rear and front panels. The wiring diagram is shown in figure 2.

Testing and Setting Up

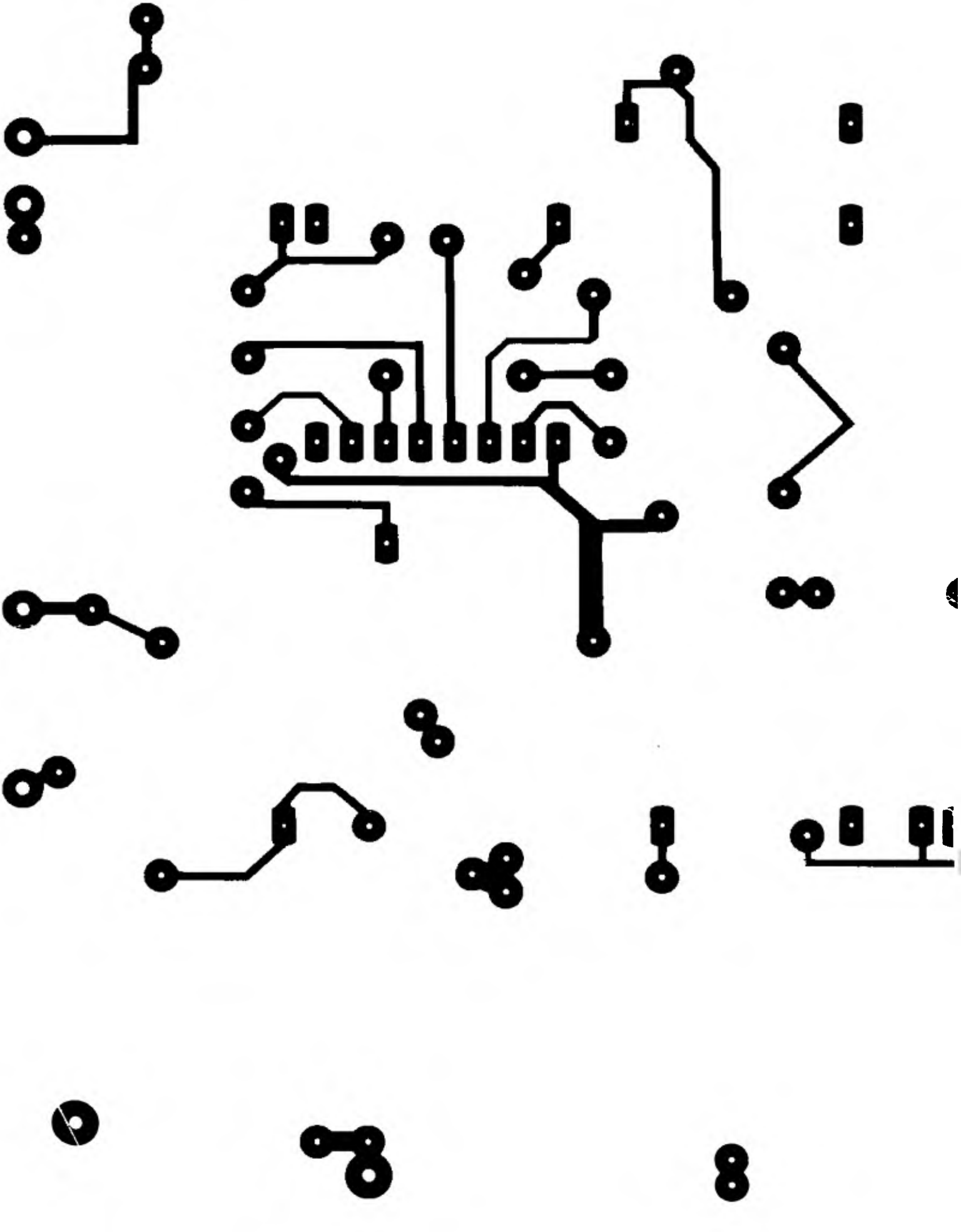
Although the circuit is protected against wrong power polarity input being applied to SK1, it is always a good move to check the polarity of the plug matches that of the socket before plugging it in. Turn the selector until any one of the three LEDs light up. The selector is a 3-pole, 4-way (selections) type allowing one off position if port D is to be isolated from the rest. In that case, all LEDs will be off. Check that the light up LEDs *do* correspond to the right port being switched. Referring to the overlay diagram, for instance, if LED A is on, a continuity test on a pin to pin basis should be carried out to see if the two single-in-line sockets RYA are connected (by the bank A relays from RYA1 to RYA8). An identical test should be run on port B and C as well.

Provided the tests are positive, you are ready to configure the ports. First make up your mind what peripheral is going into port A etc. and write down the port configurations you need. Port A has two rows of single-in-line (SIL) sockets carrying 25 pins of the DB25 connectors. Each of these pins can be routed onto its corresponding relays input socket RYA. The output of the relay also go to an identical socket RYA which could then be routed onto port D's SIL sockets. A similar procedure can be carried out on port B and C. Since port D has to accept routings from RYA, RYB and RYC, each pin on port D will have three holes reserved to allow one hole per wire. That's why there are six rows (each two rows for 25 pins) of SIL sockets for port D. Wires used for the routing will be a single core type and the diameter of it should match with the size of the holes on the SIL socket for secure connections.



ETI 1608 — HOW IT WORKS

The circuit is extremely simple electrically. The input 6V dc from the plug pack goes through D1 which only allows one way traffic to protect the circuit from wrong input polarity. The voltage drop of D1 is around 1V and the resultant voltage is smoothed by the capacitor C1 to around 5V. The relays used are 5V reed switch type with a 20mA coil. They are arranged into three banks, each bank can have relays up to eight. If the number of lines to be switched is less than eight, less relays are needed. The coils of the relays in the same bank are connected in parallel with an LED. When the bank is selected, all the relays in that bank and the associated LED will be turned on, connecting port D to the port corresponding to that bank of relays. Diode D2 is there to clamp any negative going pulses during relay witchings. Resistors R1, R2, R3 are current limiting resistors for the LEDs to limit the current flow down to 20mA when 5V is applied to the coil. With maximum relays on board, the current capability of the plug pack must be at least 20mA x 8 (8 relays) + 20mA (LED) = 180mA at least at 6V dc.



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